THESIS

BIOGEOMORPHIC PROCESSES AND ARCHAEOLOGICAL SITE FORMATION IN ABSAROKA MOUNTAINS OF NORTHWESTERN WYOMING

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY JILLIAN M. BECHBERGER ENTITLED BIOGEOMORPHIC PROCESSES AND ARCHAEOLOGICAL SITE FORMATION IN THE ABSAROKA MOUNTAINS OF NORTHWESTERN WYOMING BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS.

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ABSTRACT OF THESIS

BIOGEOMORPHIC PROCESSES AND ARCHAEOLOGICAL SITE FORMATION IN THE ABSAROKA MOUNTAINS OF NORTHWESTERN WYOMING

Archaeologists frequently associate *Thomomys taploides*, the Northern Pocket Gopher, with the loss of stratigraphic integrity (Bocek 1986; Morin 2006). Disturbance from subsurface burrowing and the redistribution of sediment can result in both lateral and vertical movement of cultural material. However, fossorial activity does not necessarily negate the research potential of a site. Burrowing mammals may actually reveal previously unidentified archaeological sites, help land managers develop effective site testing plans and evaluate site significance, and contribute to a better understanding of a region's archaeological record and past environmental conditions.

This research explores the influence of pocket gopher activity on site formation at a high elevation prehistoric flaked stone scatter in the Absaroka Mountains of northwestern Wyoming. Pocket gopher activity was documented at the site in a 1-hectare sample area surrounding a small sag pond. It was suspected the sediment pocket gophers transport to the surface while digging subsurface tunnels was eroding downslope into the small pond, burying cultural material. Archaeological data were examined in conjunction with pocket gopher behavioral patterns and geomorphic processes to better understand the affect of burrowing and sediment relocation on cultural material.

Geospatial analysis was used to identify topographic controls on burrow placement. The physical characteristics of flaked stone recovered from pocket gopher disturbed sediment were compared with artifacts located on the undisturbed site surface and subsurface artifacts collected during test excavation to identity patterns in distribution potentially resulting from gopher activity. Erosion from pocket gopher mounds was evaluated by comparing the sediment characteristics of active and abandoned burrows and using a GIS-based erosion model.

Results show pocket gopher burrows occur most frequently on north facing slopes. Neither gradient nor elevation could be shown to significantly influence burrow placement. There were differences in the locations of winter pocket gopher activity and summer activity. The physical characteristics of artifacts found within pocket gopher disturbed sediment were indistinguishable from artifacts on the site surface. Subsurface flaked stone exhibited significant differences in the artifact characteristics examined at all depths. However, the vertical distribution of artifacts at the site was not consistent with patterns noted in other pocket gopher impacted archaeological sites. The erosion model indicated sediment from pocket gopher disturbed areas at the site would be deposited in the sag pond, however the amount of predicted accumulation did not correspond with accumulation calculated using radiocarbon dated samples collected from known depths.

The impact of pocket gopher activity on the lateral and vertical movement of artifacts at 48PA2874 could not be definitively demonstrated. This project provides a general background for further research on pocket gopher impacts to archaeological material in alpine settings. With additional research the effect of pocket gopher activity on artifact distribution in high elevation environments can be better understood.

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This project would not have been possible without the help of the GRSLE field school students who spent two long weeks documenting the dirt and rocks in pocket gopher mounds. I thank fellow graduate school students Marcy Reiser, Naomi Ollie, Courtney Hurst, Robin Roberts, and Allison Bohn for their friendship and support. I greatly appreciate the edits provided by my father Larry Wiseman, Courtney Hurst, Jason LaBelle, and Erik Gantt- who all know more about pocket gophers then they wanted. I thank my mother for her unwavering confidence and support. Finally I thank Erik for his unbelievable patience and encouragement throughout the last few months of this process.

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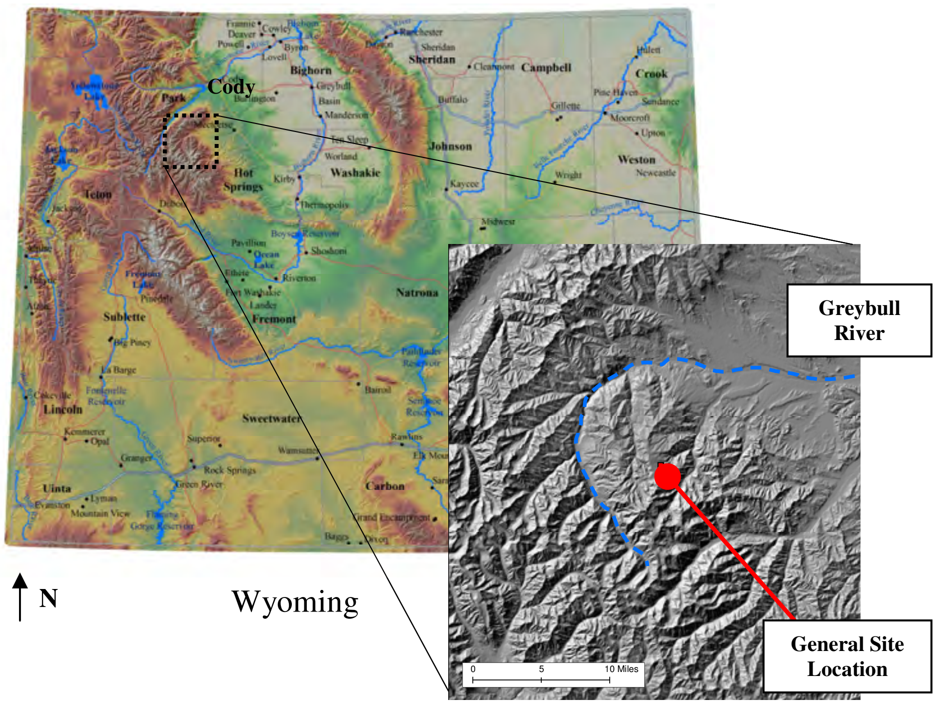
CHAPTER 1

INTRODUCTION AND BACKGROUND

Burrowing mammals exert substantial influence over the physical, chemical, and biological structure of ecosystems. For archaeologists, sub-surface faunalturbation is often associated with significant site disturbance, particularly the loss of stratigraphic integrity (Bocek 1986; Morin 2006). While horizontal and vertical relocation of cultural material can occur, fossorial activity does not necessarily negate the research potential of an archaeological site. Heavily bioturbated sites may not be able to address specific "living floor" type questions; however they can provide input on broader research questions, such as regional settlement patterns. The scale of the information sought must match the level of site integrity. The activities of subsurface organisms may facilitate site discovery, aid in the development of effective site testing plans, and contribute to a better understanding of a region's archaeological record and past environmental conditions.

The pocket gopher (Geomyidae: Rodentia) is a familiar and often lamented bioturbator. Pocket gophers are highly adaptive, occupying environments as diverse as alpine tundra and the grasslands of the high plains. Despite their ubiquity, comprehensive research addressing the impact of pocket gopher activity on archaeological material is limited (Balek 2002; Bocek 1986; Bocek 1992; Erlandson 1984; Fowler, et al. 2004; Johnson 1989; Morin 2006). Fortunately, ecologists and geomorphologists have extensively studied pocket gopher behavior and the long-term environmental affects of their activity (Gabet 2000; Gabet, et al. 2003; Hansen and Morris 1968; Huntly and Inouye 1988; Ingles 1949; Ostrow, et al. 2002; Sherrod and Seastedt 2001; Sherrod, et al. 2005; Thorn 1978a). This project couples biophysical research with archaeological data to explore the influence of pocket gopher activity on site formation processes.

Figure 1.1. Location of GRSLE Project and Research Site

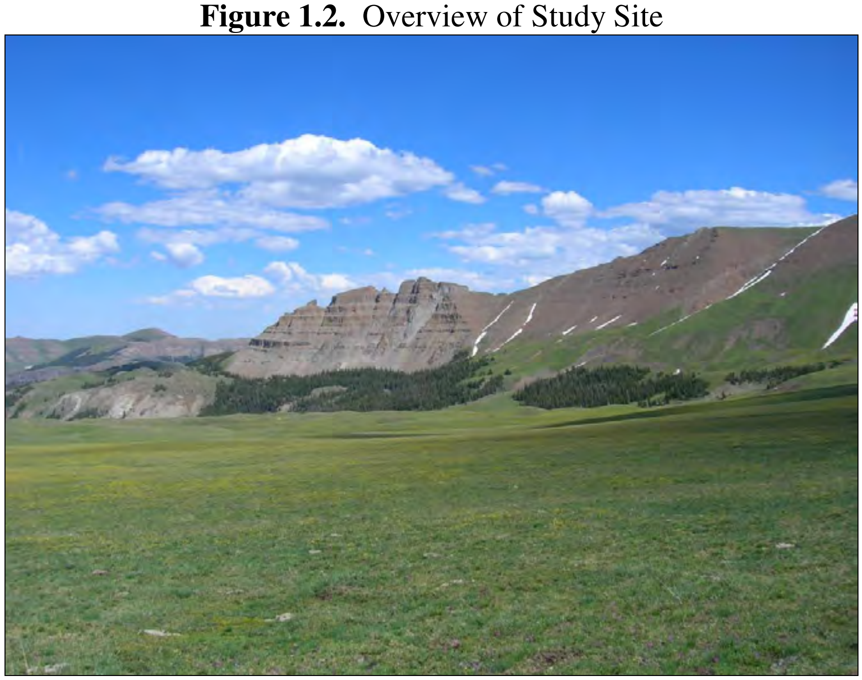


The Northern Pocket Gopher (*Thomomys talpoides)* is considered an integral component of high elevation environments (Gabet et al. 2003; Huntly and Inouye 1988; Sherrod et al. 2005; Thorn 1978). The current study examines the impact of *Thomomys talpoides* on a prehistoric lithic scatter in the Absaroka Mountains of northwestern

Wyoming (Figure 1.1). The research site (48PA2874) is located in an open alpine meadow overlooking the western Big Horn Basin.

The terrain consists of overlapping, lobate slopes that terminate in spoon shaped depressions referred to as sag ponds. The hummocky landscape is blanketed with montane grasses and forbs, creating an ideal habitat for the Northern Pocket Gopher (Figure 1.2). The sag ponds, with their deeper, finer grained sediments and thick vegetation, are surrounded by dense concentrations of pocket gopher activity. Pocket gophers create an extensive network of sub-surface tunnels, depositing the excavated sediment in small mounds on the ground surface. The magnitude of pocket gopher occupation observed during initial examination of the site area made apparent the need to evaluate the impact of faunalturbation on archaeological material. Pocket gopher disturbance has the potential to obscure or create patterns in artifact distribution, which could be attributed to, but are not a result of, cultural events.

Figure 1.2. Overview of Study Site



Photograph by L.C. Todd

Research Objectives

Pocket gophers can impact cultural material in two ways: by the direct, physical repositioning of artifacts and by the indirect geomorphic changes induced by their activities. Transformations occur at, and are relevant to the archaeological record at multiple scales. Localized movement of artifacts can alter the distribution of cultural material at a site. Spatial relationships of artifacts and features are used to infer past human activities and interpret site function.

The consideration of gopher activity is important when conducting field survey and subsurface testing or excavation. The sediment pocket gophers eject onto the ground surface may reveal buried archaeological material or conversely, obscure the visibility of surface artifacts. The churning of sediment can homogenize chronologically distinct cultural deposits or create pseudo-stratified deposits. The intensity of pocket gopher occupation, and therefore site disturbance, is linked to environmental conditions. Fluctuations in pocket gopher population over time may reflect changes in habitat. Reconstructing the history of gopher occupation may contribute to a better understanding of regional climate and landscape change.

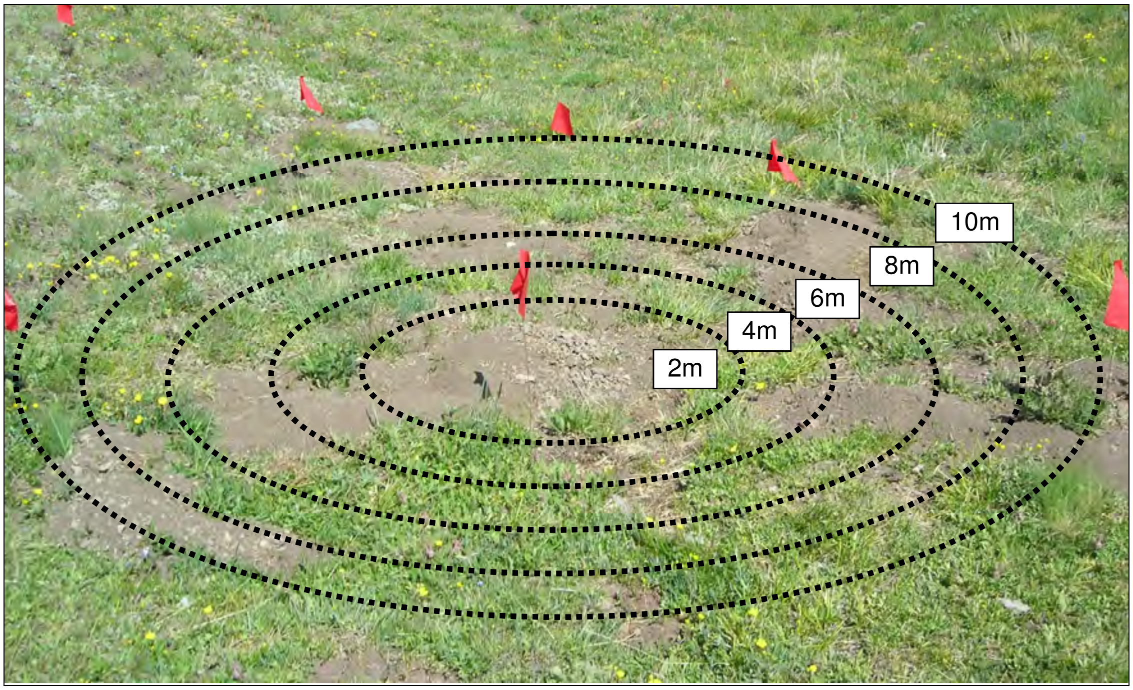
This research examines the direct and indirect affect of pocket gopher activity at 48PA2874. This analysis represents an initial, exploratory effort at examining the relationship between pocket gopher activity and archaeological site formation in an alpine setting. It is recognized that both cultural and non-cultural processes alter the record of past human activity and that the findings of this study may not be definitively attributed to pocket gopher activity. Outlined below are the research questions and how they were addressed in this project:

I. Is pocket gopher activity causing horizontal or vertical displacement of archaeological material at 48PA2874? If so, are artifacts of particular shapes or sizes preferentially transported?

To explore the influence of pocket gopher activity on surface and subsurface artifact distribution, physical characteristics of artifacts recovered from pocket gopher mounds were compared with those located on the undisturbed ground surface and those found in test excavation units. Artifacts were evaluated using a variety of shape indices calculated from axial measurements. These indices provide a quantifiable value to attributes and form that can then be used to make comparisons of different artifact groups. Trends in shape characteristics help determine if pocket gophers are more likely to transport particular forms of artifacts, such as equidimensional material rather than long, thin objects. Maximum length and the following shape indices were used in this analysis: elongation (b/a), flatness (c/b), blockiness/roundness $(bc/a^2)^{1/3}$, and weight $(a+b+c)^{1/3}$, where *a* equals length, *b* equals width, and *c* equals thickness (de Scally and Owens 2005).

Disturbance to surface archaeological material was examined by comparing artifact characteristics based on distance from the pocket gopher mound. If pocket gophers are altering the spatial relationships of surface material, artifacts closest to the disturbed sediment are more likely to exhibit patterning in density, size, or shape. In this analysis surface artifacts were examined as a whole assemblage and then grouped by circular, concentric, 2-meter zones that radiate out 10 meters from the center of pocket gopher activity (Figure 1.3).

Figure 1.3. Diagram of Artifact Analysis Zone Radiating out from Burrows



Photograph by L.C. Todd

Vertical distribution of cultural material was investigated by comparing artifacts located in pocket gopher mounds with those recovered from test excavation units. Characteristics were analyzed by depth, in 5 centimeter (cm) intervals. Some research has shown pocket gopher activity results in subsurface stratification of material by size (Bocek 1986, 1992; Erlandson 1984; Johnson 1989). Patterns in artifact distribution that have been linked to pocket gopher activity are compared with data from test excavation to evaluate evidence of disturbance at 48PA2874.

II.   What is the relationship of pocket gopher mound location to topographic features? If pocket gophers seek out the most suitable habitat, can areas of occupation, and by extension, areas of archaeological disturbance, be predicted?

A considerable amount of pocket gopher activity surrounded sag ponds at 48PA2874. To systematically evaluate this visual observation, pocket gopher activity was documented in a 1-hectare area surrounding a dry sag pond. Gopher activity was identified by the presence of small mounds of disturbed sediment and tunnel casts, also called soil cores, soil casts, eskers, or ropes. Tunnel casts form on the ground surface when burrowing occurs beneath snow cover. Sediment is compacted upward into the snow, creating a tube-shaped soil cast that is revealed upon snowmelt (Figure 1.4).

Figure 1.4. Evidence of Winter Pocket Gopher Activity
a. Tunnel emerging from snow bank, b. Tunnel-shaped soil casts after snowmelt

Photographs by L.C. Todd

The surface evidence of pocket gopher occupation was mapped and burrow characteristics recorded. Documentation included recording the amount of displaced sediment, the area covered by ejected material, the type of burrow (mound or soil core), screening for the presence of archaeological material, and identifying occupation status (actively used or abandoned). Pocket gopher burrow location data and associated attributes were input into Geographic Information System (GIS) software ESRI ArcMap 9.2. The program was used to examine burrow density in relation to slope, aspect, and elevation within the 1-hectare sample area to uncover patterns or preferences in burrow location.

III. How does the sediment disturbed by burrowing contribute to geomorphic processes at the site; specifically, erosion? How is this affecting archaeological material?

The sediment transported to the ground surface by pocket gophers is susceptible to redistribution by alluvial, colluvial, and aeolian processes. Sag ponds at 48PA2874 act as mini-catchment basins for eroded sediment. It is suspected that the long-term accretion of particulate matter in the sag ponds is an environment conducive to burying archaeological materials. Due to the density of burrows surrounding the sag ponds, sediment disturbed by pocket gopher activity could significantly contribute to deposition. This possibility was examined in two ways. One, sediment properties of actively occupied gopher burrows were compared with the properties of abandoned burrows. If redistribution of sediment disturbed by gopher activity is occurring, the freshly ejected sediment from occupied burrows should have different characteristics than that of inactive, deflated burrows. Since the inactive burrows have been exposed to erosion for a longer period, it is expected abandoned burrows would have less volume on average than active mounds. As clay and silt are more easily eroded than larger material like sand, therefore inactive burrows should contain a lower proportion of fine particulates.

The second way this question was evaluated used a GIS-based erosion model. The model predicts the path and amount of material eroding from a specified point. The travel route is determined by the slope that was calculated from high resolution elevation information collected during field work, and the volume of sediment associated with each pocket gopher burrow. As silt and clay are most easily transported, only the average proportion of fine particulates comprising burrow sediment was input into the model. The results show if sediment, 1) was likely to reach the sag pond and 2) the amount of potential accumulation.

IV. How accurately does the GIS model predict the rate of sedimentation and what can this tell us about past environmental conditions?

The accuracy of the GIS erosion model was evaluated by comparing predicted deposition with the actual accumulation within the pond. The rate of sediment accumulation was determined by radiocarbon dates of charcoal samples taken from known depths during the test excavation of four 1 by 1 meter (m) units located in the pond area. The results of the GIS erosion model are interpreted as representing the amount of sediment accumulation resulting from erosion of pocket gopher disturbed sediment occurring within one year. The of predicted deposition was multiplied by the number of years indicated by the radiocarbon dates, thus approximating the rate of accumulation predicted to occur in that time span.

Long-term sedimentation rates are closely linked with climate. Erosion of pocket gopher mound sediment is driven by the frequency and intensity of precipitation events, snow accumulation, and wind. The amount of sedimentation will vary with changing environmental conditions. For example, an extended period of warming can result in a diminished snowpack, lessening the amount of deposition that results from the transportation of sediment by melt water. A greater amount of snow will increase the sediment yield from overland flow during the spring thaw. The vulnerability of sediment to erosion is impacted by the density and composition of vegetation. Vegetation communities are determined largely by climate, and in high elevation environments strongly influenced by sediment brought to the ground surface by gophers. These biotic-abiotic interactions form one of the many non-linear feedback systems that shape alpine ecosystems. Knowing the rate of accumulation in different time periods can begin to suggest paleo-ecological conditions. The scale of this research project cannot reconstruct the former climate; however it proposes a method that combines biophysical studies with archaeological data to identify changes over time.

Theoretical Perspective

Historically, the goal of the archaeologist centered on developing a better understanding of past human behavior through the study of material cultural (Trigger 1989). The realization that the record of human action consists of evolving interactions between social and environmental factors has encouraged many contemporary archaeologists to take an interdisciplinary approach to archaeological research (Schiffer 1987). An archaeological assemblage is not a direct reflection of past human behavior. After abandonment, the material record is transformed by both cultural and biophysical processes. Before archaeology can be used to infer human behavior, it is crucial to identify the taphonomic processes shaping the distribution and types of materials present today (Schiffer 1987:7). Reconstructing the taphonomic history is not only imperative to understanding the human component of a site, but can also provide information on past ecological conditions and changes.

Background to the GRSLE Project

Research was conducted as part of the Greybull River Sustainable Landscape Ecology (GRSLE) project. In 2002 GRSLE, in conjunction with the Laboratory for Human Paleoecology at Colorado State University (CSU), initiated a longitudinal, multi-disciplinary program to document and monitor the environmental and cultural processes governing the human use of landscapes. GRSLE's philosophy- "Science, Stewardship and Sustainability" (Todd 2004) - emphasizes archaeological research with multi-purpose applications. Archaeological data are not restricted to the interpretation of past human behavior; rather archaeological research is in a prime position to monitor modern human impacts on the environment and to help link research in the natural and social sciences.

Unlike the heavy traffic incurred by nearby National Parks (Yellowstone and Grand Teton), the upper Greybull watershed currently receives far less recreational use. This comparatively pristine wilderness is on the cusp of a great shift in land use as the area is becoming increasingly attractive to hikers, hunters, and horseback riders, as well as to oil and gas companies (Todd et al. 2004). The GRSLE project has the unique opportunity to document environmental conditions prior to extensive commercial and recreational use. Through creating interdisciplinary baseline data sets, researchers will have an unbiased, reproducible way to monitor human-environmental interactions. Archaeology can provide land managers with the scientific data needed to decide which elements of the ecosystem are least resilient as well as help determine the success of outreach and educational programs (Todd et al. 2004).

48PA2874: Introduction to the Research Site

The GRSLE project area focuses on the remote, little accessed tributaries of the upper Greybull River in the central Absaroka Mountains (Figure 1.1). Prior to the GRSLE research, only nine prehistoric archaeological sites had been documented in the project area (Burnett 2005). Since 2002, graduate students, Colorado State University field school participants, and volunteers have recorded over 73,299 artifacts and identified over 384 previously undocumented archaeological sites (Todd, personal communication).

The research site, 48PA2874, is a prehistoric lithic scatter located on a broad alpine meadow at an elevation of 3100 m. The weathering of relic landslides has created a rolling topography interspersed with seasonally-filled sag ponds. The site encompasses approximately 2.8 hectares and contains over 2,400 artifacts. Diagnostic projectile points indicate the site was used for over the last 9,000 years. Historically the area was summer range for cattle and is still part of the Greybull C&H grazing allotment. No historic artifacts or significant evidence of modern recreational use (ATV tracks, trash, collector piles) was encountered. The site has a diverse artifact assemblage with both local and exotic toolstone source materials. Discrete concentrations of lithic debris with clusters of fire-affected artifacts are present, suggesting more than ephemeral use of the site. The site is located in an open grassland, making it unlikely these clusters of fire-affected artifacts are a result of wildland fires or the burning of individual tree wells, although additional research to refine our understanding of tree-line movement over the last 9,000 years is needed to fully discount this possibility. The intra-site patterning is currently interpreted as multiple episodes of human activities surrounding a hearth.

Thesis Organization

Chapter 2 reviews the geomorphic processes common in high elevation environments and how they have influenced topographic features and archaeological material at 48PA2874. This is followed by a comprehensive examination of pocket gopher ecology, behavioral patterns, and the physical impact of burrowing on landscapes. An overview of previous archaeological research on pocket gopher activity and artifact distribution is provided. Chapter 3 outlines the research methods, describes the site surface assemblage, the results of test excavation, and the information collected on pocket gopher burrows. Chapter 4 analyzes test excavation data, reports the results of the erosion model, and compares the physical characteristics of lithic debris recovered from pocket gopher disturbed areas with the surface assemblage and subsurface artifacts. The results are examined in conjunction with previous archaeological and ecological research. Chapter 5 discusses conclusions drawn from the study, outlines future site-specific research directions, and delves into broader issues of the influence of pocket gophers on biogeomorphic processes and their affect on the archaeological record in montane environments.

CHAPTER 2

ENVIRONMENT AND LANDSCAPE FORMATION

Understanding the evolution of natural systems at multiple spatial and temporal scales is key to developing interpretative frameworks in archaeology. This research project focuses on biophysical interactions occurring at a site-specific location over a geologically short timeframe. The nature of this study does not allow for an in-depth examination of the many geomorphic transformations that have occurred, and are occurring at 48PA2874. However, there are landscape formation processes common to high elevation settings that can be applied to the research area (Hall and Lamont 2003; Hall 2003).

Characteristics of landscapes are a function of past environmental conditions and, in many areas, human modification. Ecological systems are not static and modern conditions may not reflect the former climate or topography. Geomorphic events modify the physical environment and can transport, bury, or reveal artifacts. Understanding post-depositional changes affecting site context is essential to legitimately infer function from the material record of human activity (Schiffer 1987).

This chapter provides an overview of some of the significant geomorphic processes that have shaped and continue to change 48PA2874. Broad, landscape-scale changes and site specific methods of sediment transportation are addressed. These include multiple forms of mass movement, cryoturbation, and alluvial and aeolian erosion. This is followed by a brief discussion of key archaeological research conducted on mass wasting and cryoturbation. The chapter concludes with a detailed examination of a third geomorphic process the focus of this research, faunalturbation by pocket gophers.

Site Setting and Landscape History: A Brief Summation of Long-term Processes

The GRSLE project area is located at the headwaters of the Greybull River in the Absaroka Mountains of northwest Wyoming. The Absaroka Mountains are part of geologic feature called the Absaroka volcanic province (AVP) that stretches 250 kilometers (km) from southwestern Montana through northwestern Wyoming, covering a total of 23,310 km². The AVP formed between 53 and 38 million years ago during the Eocene Epoch when volcanic activity created a belt of high elevation, andesitic stratovolcanoes (Malone, et al. 1996). The eruptions caused lava, ash, and mudflows to fill rivers, forming a broad, high elevation volcanic plain (Hughes 2003). Rapid fluvial and aeolian erosion transported the newly deposited volcanic material into adjacent basins, forming a thick layer of redeposited debris (Malone, et al 1996:481). Over time, geomorphic processes have formed the present-day landscape of steep drainages, broad alpine meadows, and glacial outwash terraces (Reitze 2004).

Modern climate varies with micro-environmental conditions, topographic features, and elevation changes. Weather data collected by the Western Regional Climate Center (WRCC) at the Sunshine 2NE station, located north of the project area, indicate annual precipitation is approximately 35 cm. Winter temperatures average between -

14ºC and -9ºC and summer averages 14.8ºC (WRCC 2010). To a certain degree, physical characteristics of the modern landscape can be grouped by elevation. Elevation in the Absarokas ranges from 2200 meters above sea level (masl) to 4009 masl at Francs Peak. The highest ridges of the Absarokas consist of deflated bedrock with patches of glacial regolith, colluvial debris, and alluvial deposits. Slope wash and colluvium, with lesser amounts of surface bedrock, alluvium, and glacial deposits comprise the mid-slope areas. The landscape below the higher-gradient mid-slopes is dominated by landslide deposits (Burnett 2005).

Vegetation in drainages and north-facing slopes consists primarily of coniferous forests. Mountain Big Sagebrush (*Artemisia tridentate*) is often found on the dryer south facing slopes (Burnett 2005:7). Montane grasses and forbs, including blue grama (*Boutela chondrosum*) and mountain sorrel (*Oxyria digna*) are present on the large open meadows in the sub-alpine and alpine environmental zones. Small islands of spruce-fir and white bark pine are present in some of the upland meadows. Tree lines are not stationary and have shifted with changes in temperature and moisture regimes. This is clearly indicated by the presence of "ghost forests" within the project area (Reiser 2005).

A number of artiodactyls occupying the area would haven been attractive to Native American hunters, including mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), pronghorn (*Antilocapra americana*), and big horn sheep (*Ovis candensis*). Although not present today, bison (*Bison bison*) were present historically and prehistorically in the Absaroka Mountains (Frison 1991; Ollie 2007). Other mammalian species include Grizzly bears (*Ursus arctos horriblis*), black bears (*Ursus americanus),* wolves (*Canis lupus*), and coyotes (*Canis latrans*). Smaller mammals found in the area consist of rabbits (*Lepus sp*.), marmots (*Marmota flaviventris*), badgers (*Taxidea taxus*), ground squirrels (*Spermophilus sp*.), and the impetus for this research, northern pocket gophers (*Thomomys taploides*).

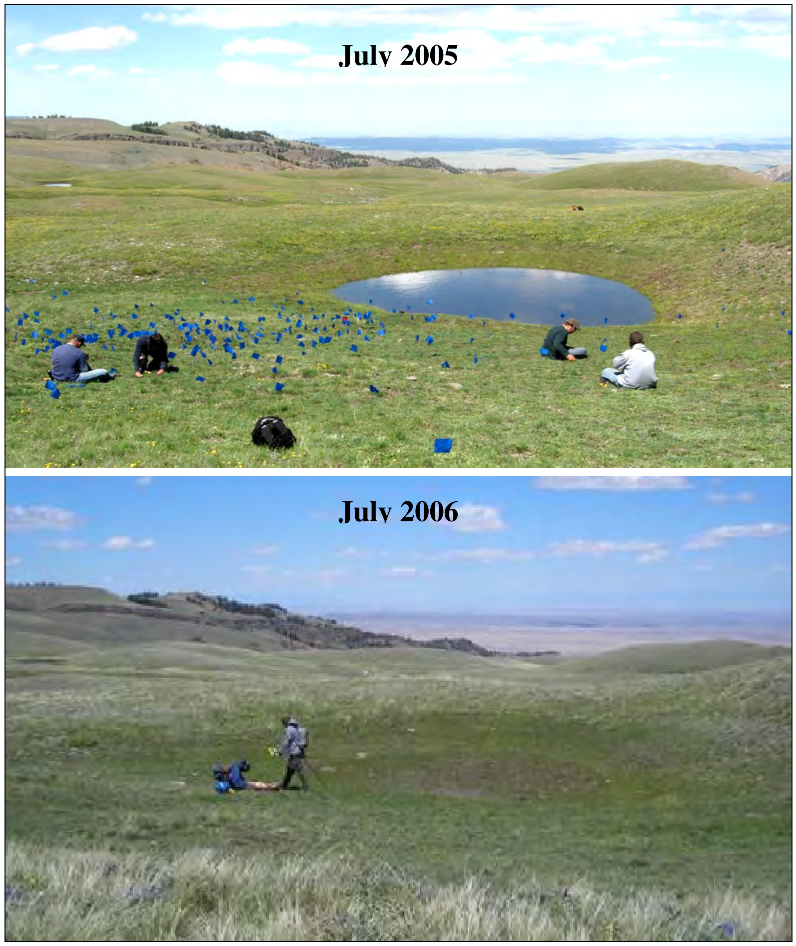
Landscape Formation at 48PA2874

48PA2874 is located in an upland meadow dissected by moderate-sized gullies and small rills. The superimposed, bulbous slopes range in gradient from 2º to 30º with the majority of the site between 5º and 6º. Elevation at the site ranges from 3075 meters to 3105 meters. The higher portions of the hill slopes are mostly deflated with areas of exposed bedrock, thin regolith, and sparse, patchy vegetation. It was informally noted that bedrock had significant lichen and moss growth, which has the potential to suggest stable environmental condition (Benedict 2009). Alluvial and colluvial transportation of upslope material has created relatively deep toe-slope deposits. As shown in Figure 2.1, vegetation across the site is drought sensitive, and varies greatly between wet and dry years. In general, vegetation consists of bunch grasses, forbs, and abundant wildflowers in wet years.

Broad Geomorphic Processes: Rotational Slides and Earthflows

The disconformity between the ancient sedimentary deposits and the overlying reworked volcanic material formed a landscape prone to mass-wasting (Ollie 2007:3). Mass-wasting refers to geomorphic processes that are induced by gravity (Ritter et al. 2002). A mass wasting event can range from the downslope movement of a single particle to a massive debris-flow that alters an entire watershed. The basic physical

Figure 2.1. Annual Variation in Moisture Regimes at 48PA2784

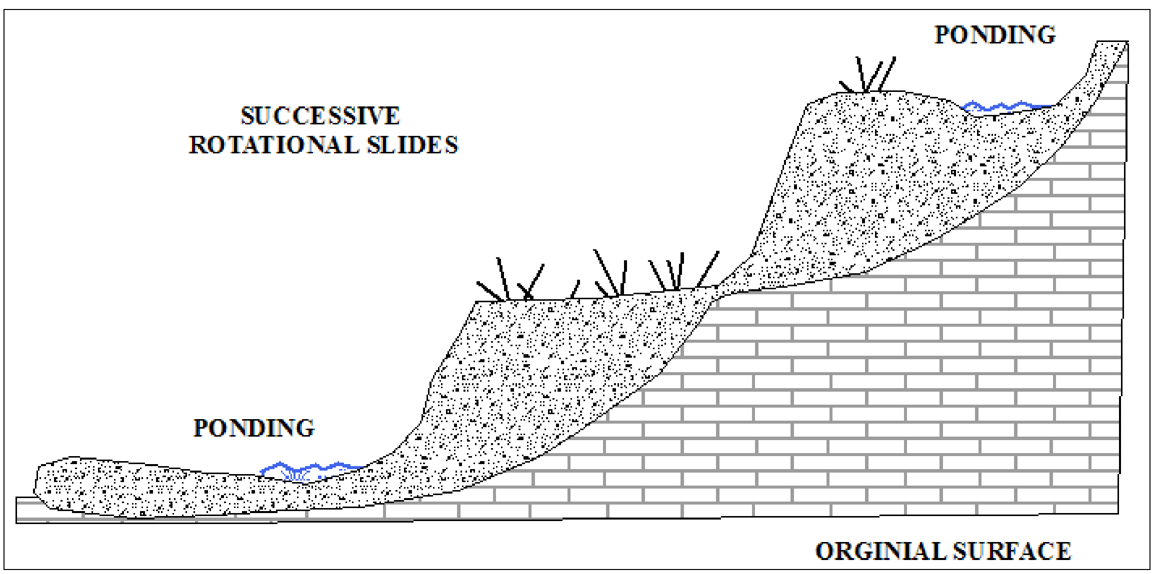


Photographs by L.C. Todd

structure of the landform on which 48PA2874 is located was created by multiple landslide events occurring prior to the Pleistocene-Holocene transition (Ollie 2008). Landslides began as rotational slides or slumps which liquefied into earthflows downslope (Dikau et al. 1996:43). A rotational slide occurs when a distinct mass of sediment and/or rock rotates along a curviplanar line parallel to the contour of the slope (Figure 2.2). At the initial point of failure, the mass of sediment and rock tilts backward while being displaced downslope, forming a scarp where movement began. This is followed by a flattening or "slope reversal" (Dikau et al. 1996:49).

When rotational slides liquefy downslope they are termed slump-earthflows (Ritter 2002). The transition to a flow can cause the toe area to rise or bulge and form lobate terrain features, like those found at 48PA2874 (Dikau et al. 1996:49, 51). These events can create irregular drainage patterns and often develop ponds or boggy areas at the head of the slump or between the main body and the toe (Figure 2.2) (Dikau et al. 1996:48). Rotational slides can be small occurrences that result in the formation of small terracettes, or large, expansive movements that cover entire landforms (Dikau et al. 1996:45).

Figure 2.2. Characteristics of a Rotational Slide
Note ponding at the head of the slide and at the base of the lobate toe



(Figure based on Dikau et al 1996:Figure 4.2; Ritter 2002:Figure 4.37A)

Subsequent geomorphic processes have altered topography at the site. These include other forms of mass wasting, such as heave, soil creep, and solifluction, and their cryogenic counterparts, frost heave, frost creep, and gelifluction, as well as alluvial and aeolian erosion. At 48PA2874 the dominant landform features, turf-banked lobes and terraces, were formed from the interaction of solifluction and frost action

Site-Specific Geomorphic Processes: Mass Wasting

Mass wasting events vary in their intensity and spatial extent. Like all geomorphic transformations mass movements are a function of multiple factors, such as terrain, weather/climate, sediment characteristics, seasonal vegetation, and land use among others (Ritter et al. 2002). Heave and soil creep, two slow mass wasting processes occurring at 48PA2874, work in conjunction with one another. Heave is the vertical expansion of surface material and soil creep is the gravitationally driven downslope movement of sediment. Soil creep occurs when boundaries between the mineral structures are weakened enough to move material downslope, parallel to the ground surface, without causing mass failure (Roering 2004; Selby 1982). The loss of particle cohesion makes the slope vulnerable to additional mass wasting and other forms of erosion (Gatto 2000). Heave decreases with depth and is thought to cease by 20 cm below the surface. Research on the rate of sediment movement due to creep indicates particles can travel between 0.1 to 15 mm/yr on vegetated soil and up to 50 cm/year on unvegetated slopes where creep is enhanced by freeze-thaw cycles (Ritter et al. 2002:105). The impact of soil creep may be barely detectable over short time frames, but can be a significant agent of change over the long-term (Selby 1982:117).

Frost Action, Solifluction, and Snow

When soil creep is caused by freeze-thaw cycles, it is referred to as frost creep. The degree of frost creep depends on the number of freeze-thaw events and soil properties such as texture, moisture, and temperature (Gatto 2000; Millar 2006). Frost heave occurs as the soil matrix freezes and forces larger particles toward the surface. As the ice melts, fines accumulate in the void left by the particle, resulting in a surface covered with only larger debris (Waters 1992). Loose soil with low clay content, characteristics of pocket gopher mound sediment, promote the freeze-thaw process (Hilton 2003). Frost creep contributes to the formation of distinctive lobate-shaped landforms and low, step-like terracettes (Benedict 1976) both of which are present at 48PA2874.

Freeze-thaw processes and solifluction generally co-occur on the same landscape feature, in opposing seasons (Benedict 1970). Solifluction is a form of mass wasting defined as the slow downslope movement of waterlogged sediment. Solifluction is favored by sediment that overlays an impermeable surface such as frozen ground or by deposits that have differing permeability, such as the strata overlaying the slump-earthflow at the site. As surface layers thaw, the cohesion of the upper deposits are weakened, allowing sediment to flow over the impermeable stratum (Benedict 1970:170). When solifluction is caused by the melting of snow or ice, the process is often referred to as gelifluction.

The influence of snow on geomorphic processes is significant (Caine 1995; Thorn 1978b). Snow surfaces are able to trap fine aeolian particles (see Figure 1.4a). Sediment accumulation in snow patch sites can be twenty to thirty times greater then adjacent snow-free areas (Thorn 1978b:422). Snow at 48PA2874 is unevenly distributed, resulting in the differential accretion of fine particulate matter. The transportation of fines in melt water from snow patches produces localized concentrations of sediment (Thorn 1978b:417). Sheet wash from snow-melt is a major contributor to sediment yield; and as discussed below pocket gophers are particular active beneath snow cover (Thorn 1978b:423).

Landforms in High Elevation Environments: Turf-Banked Terraces and Lobes

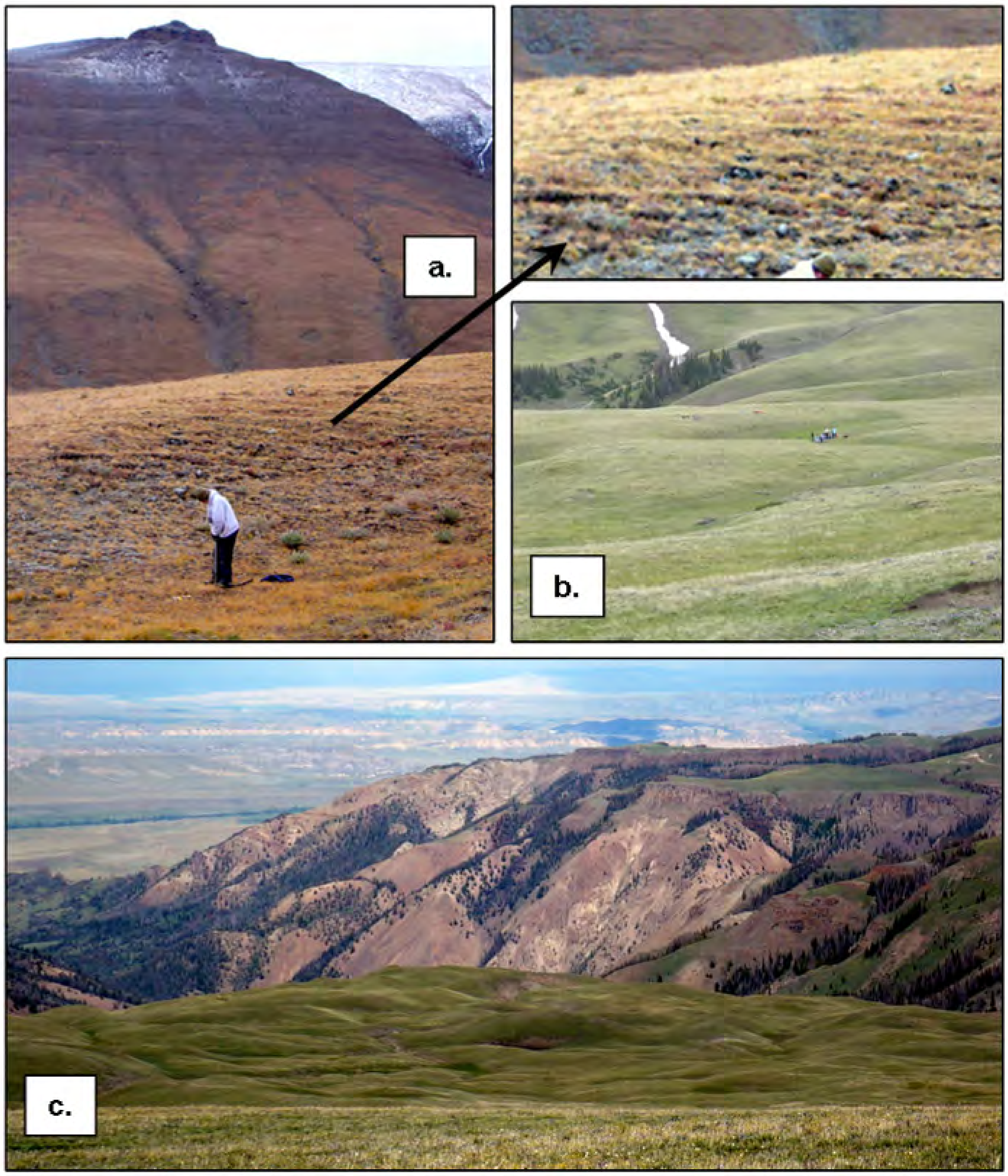
Solifluction and frost action results in two types of landforms present at the site, turf-banked lobes and turf-banked terraces. Turf-banked lobes are "lobate accumulations of moving soil that lack conspicuous sorting" (Benedict 1970:172). The lobe or tongue-shaped features bulge at the toe, overhanging the riser on which it forms (Benedict 1970:177) (Figure 2.3b, c). At the back of most lobes are "spoon-shaped" depressions or sag ponds (Benedict 1970:172). Turf-banked lobes form most readily on moist slopes with gradients between 4º to 23º and where snow is unevenly distributed like at site 48PA2874 (Benedict 1970:172; Ritter et al. 2002:386). In terrain with turf-banked lobes, snow accumulates in the depressions and drainage ways, leaving the lobe exposed to erosion by wind. Wind-blown sediment from exposed areas are deposited downslope and along the edges of the lobe (Benedict 1970:171).

Solifluction and frost action also create turf-banked terraces. Turf-banked terraces are similar to lobes except that they form unsorted, stair step-like landforms (Benedict 1970:170). Turf-banked terraces are present where snow accumulation occurs evenly across the landform on slopes ranging from 2 to 19º. Turf banked terraces more readily form on lower, concave slopes above ponds, but can also be found on convex slopes. Miniature turf-banked terraces, called *Dryas*-banked terraces are multiple, parallel, linear accumulations of sediment that roughly follow the slope contour (Figure 2.3a). The terraces result from the interaction of the prevailing winds and surficial frost creep (Benedict 1970:171).

Studies conducted by Benedict (1970) on turf-banked lobes and terraces in the front range of the Colorado Rocky Mountains showed solifluction transports sediment between 0.4 cm to 4.3 cm per year. Benedict found sediment movement is affected primarily by gradient and moisture content, while temperature and soil texture had little impact on displacement rates (Benedict 1970:165). The rate and driving force of movement varied between locations on the lobe. Solifluction proved to be most effective on the saturated axial portion of the lobe while frost creep dominated the outer edges (Benedict 1970:166). The rate of movement averaged 3 mm/year at the edge of the lobe to 43 mm/year along the axis. Movement was greatest in the surface layers of the soil and occurred only within the upper 50 cm of sediment (Benedict 1970:179).

The slow downslope movement of turf banked lobes and terraces have the potential to transport archaeological material. In solifluction lobes, the slow, downward movement of surface sediment oozes under older deposits, results in older sediment on the ground surface (Hilton 2003:169). The result is a landform with chronologically inverse stratigraphy which could significantly impact the interpretation of archaeological sites. The soil profile resulting from solifluction is distinct and can be easily identified when aware of the process.

Figure 2.3. Turf-banked Lobes and Terraces Present at 48PA2874
(a) Overview of miniature turf-banked terraces, formed by frost creep and wind; arrow points to detail, **(b)** Overlapping turf-banked lobes, **(c)** Hummocky terrain, a result of relic slump-earthflow events.



Sediment Transportation

Sediment characteristics such as clast size, orientation, and stratification provide information on the manner of deposition. Sediment movement by overland flow generally exhibits moderate sorting, weak-to-no orientation, and variation in particle size. Deposits are massive (uniform) with dispersed, laminated lenses when the flow of water is both rapid and not highly concentrated with sediment (Bertran and Texier 1999). Areas that have massive deposits with no lenses are a result of either "hyper-concentrated flow accumulation" or slow deposition resulting from processes such as rain splash, freeze-thaw, and bioturbation (Bertran and Texier 1999:100).

Energy is needed to transport sediment downslope. The entrainment capacity, or kinetic energy, generated from rainfall is a function of the duration, intensity, frequency, and amount precipitation (Selby 1982:84). The power of fluvial processes is also influenced by external factors, including soil characteristics, vegetation type and density, gradient, and microtopographic features (Selby 1982:83). Soil matrix properties, such as cohesion and pore space determine infiltration capacity and retention of water (Bryan 2000). Thick vegetation can inhibit the movement of water over the ground surface. Small, seemly insignificant topographic differences make erosion spatially discontinuous. The following section addresses methods of sediment transport that occur at 48PA2874, including interrill, rill, and pipe erosion (Bryan 2000: 387; Gatto 2000:147).

Overland Flow

Interrill or sheet erosion refers to the detachment and transportation of particulate matter by rainfall or runoff. Rainsplash energy dislodges sediment upward and away from the initial impact zone. The force behind splash erosion can be enhanced by wind or obstructed by vegetation (Bryan 2000:387). The amount and size of pore space in a soil determines the infiltration capacity. Once pore space is filled the soil becomes saturated and ponding can occur in even the smallest depressions, which facilitates overland flow. Overland flow transports sediment over the ground surface in broad, shallow sheets or in threads between vegetation. Threads of moving water can form rills and the convergence of rills can result in gullies (Selby 1982:99). Gatto (2000:148) reports erosion in rills "exceeded that on interrill surfaces by a factor of 40 on an 11° slope" and can account for as much as 80% of sediment erosion on hill slopes.

Rill formation can be facilitated by small topographic characteristics, changes in vegetation, human land use, and animal activity (Bryan 2000:390). Incomplete vegetation coverage, which is present at 48PA2874, allows frost action, rain splash, and surface wash to occur between clumps of vegetation (Selby 1982:100). Selby (1982:87) notes overland flow is significant in mountain environments where slopes, exposed rocks, and thin soils "promote" runoff. Entrainment of particulate matter by surface flow concentrates at the base of slopes and hollows (Selby 1982:94). Sheet wash is extremely effective in transporting sediment disturbed by animals (Selby 1982:104). The material loosened by pocket gopher activity is much more vulnerable to erosion than adjacent, undisturbed sediment.

Overland flow and rill formation often over-shadow the role of sub-surface erosion (Wilson 2008:1858). The transportation of water beneath the ground surface enhances the impact of surface processes, particularly the formation of gullies, by decreasing soil cohesion, increasing seepage, and from pipe erosion (Wilson 2009). Pipe erosion, the movement of water through a subsurface soil pipe or interconnected macropores is a significant process as burrowing animals like the pocket gopher create an extensive network of subsurface tunnels (Bryan 2000:395; Ritter et al. 2002:139).

Research conducted for the National Science Foundation's Long-term Ecological Research program (LTER) on Niwot Ridge, near Boulder, Colorado documented sheet wash entering pocket gopher "…tunnels only to emerge a few meters downslope with sufficient force to form a fountain 10-20 cm high" (Thorn 1978:184). The intense piping of water through gopher tunnels causes tunnel systems to collapse, leading to the formation of gullies (Reichman and Seabloom 2002). According to Ritter et al. (2002:139), piping can result in up to one-fifth of erosion on hill slopes.

Impact on Archaeological Material

Mass wasting, cryoturbation, and alluvial processes can have a significant effect on the distribution of archaeological material. Heave and soil creep preferentially move heavy and dense artifacts downslope (Rapp 1998). Studies have shown freeze-thaw processes have a substantial impact on the translocation of lithic debris, particularly in conjunction with other geomorphic process (Hilton 2003). As might be expected, there is an inverse relationship between depth of burial and artifact movement; surface material is transported a greater distance, in less time than buried material (Hilton 2003:169). Elongated artifacts are more readily reoriented by cryoturbation and are prone to upward movement. The greater the length and/or the greater the effective height the more likely it is an artifact will be impacted by freeze-thaw cycles (Hilton 2003:197). Experimental research conducted by Hilton (2003) showed artifact movement attributed solely to freeze-thaw cycles ranged from 0.7 cm to 31.7 cm. Artifacts exposed to both frost action and other geomorphic processes moved a significantly greater distance, between 6 cm and 136 cm. Small flakes (5 to 10 mm width) in the exposed unit were particularly prone to lateral transportation; on average moving 45.7 cm further than larger material. The movement of the exposed artifacts corresponded to the direction of the prevailing winds, while those impacted only by freeze-thaw cycles trended downslope. It was noted that many artifacts became partially buried and oriented vertically, which inhibited horizontal movement (Hilton 2003:183). Flake relocation caused by frost action not only moved artifacts shorter distance, but also showed no significant or predicable sorting by size or shape.

Pocket Gopher Ecology and Archaeology

The pocket gopher can be an important component in ecosystem function and diversity (Huntly and Inouye 1988; Ostrow et al. 2002). Nutrient availability in soil (Litaor, et al. 1996), the composition of vegetation communities (Sherrod, et al. 2005), the presence of vertebrate and invertebrate species (Ingles 1952; Ostrow, et al. 2002), and topographic features on multiple spatial scales (Inouye, et al. 1997), are all, in part, structured by pocket gopher activity. Subsurface tunneling and the redistribution of sediment also affect archaeological sites. Pocket gophers homogenize soil horizons and can change the stratigraphic relationships of buried cultural material (Bocek 1986; Erlandson 1984; Johnson 1989; Morin 2006). Knowing the habitat parameters, behavioral patterns, and the physical changes induced by burrowing will help archaeologists identify locations of pocket gopher occupation and potential impacts to archaeological material.

This section provides an overview of pocket gopher ecology in high elevation environments with particular emphasis on the Northern Pocket Gopher, the species present in the project area. This section is followed by a review of previous studies of pocket gopher impacts to archaeological sites.

Pocket Gophers: Behavior and Habitat

Pocket gophers are solitary herbivores that spend up to ninety-nine percent of their lives underground (Thorn 1978). There are over 30 species of pocket gophers, each associated with, and adapted to, particular environments (Bocek 1986). Although they exploit diverse habitats, from the tall-grass prairie to alpine tundra, all species of pocket gophers exhibit similar behavioral traits (Thorn 1978). Of the many pocket gopher species, the Northern Pocket Gopher (*Thomomys talpoides*) is the most widely distributed, occupying an area spanning north-south from Manitoba to New Mexico and east-west from the Midwest to California (Gabet et al. 2003:265).

Burrow Systems

Pocket gophers individually occupy subsurface burrows. The burrow system has four components: multiple surface openings, a network of feeding tunnels, a den chamber, and separate compartments for food storage (Bocek 1986; Erlandson 1984). The extensive system of tunnels represents a single gopher's territory or "home range" (Romanach, et al. 2005). Territories are relatively fixed and generally do not overlap (Ingles 1952; Thorn 1978). The length and areal extent of foraging tunnels varies with environmental characteristics. The more food available for consumption, the smaller the area the burrow system spans (Romañach et al. 2005); and the less potential for impacts to archaeological material.

Pocket gophers line their dens with finely shredded grasses. Depending on sediment characteristics and compactness, dens are on average located 50 cm below the ground surface (Bocek 1986; Erlandson 1984). They average 20 cm in height and 24 cm in diameter (Ingles 1952). Food caches are located in separate compartments connected to the nest through the underground tunnel system (Ingles 1952). In areas abandoned by pocket gophers where surficial evidence of occupation no longer exists, pocket gopher activity may be identifiable by subsurface clusters of vegetation or excrement.

Slight differences in soil type and vegetation communities have an impact on pocket gopher distribution. Soil depth, temperature, moisture content, hardness, and rockiness influence the presence and density of burrows (Beck 1965). The rate of mound formation changes significantly with water content of soil. When soil moisture is less than 9% or greater then 18% burrowing rates drop dramatically (Miller 1948). Soil frozen between 5 to 10 centimeters deep inhibits tunneling, forcing pocket gophers to relocate burrows in cold periods (Ingles 1949:344). During spring thaw, pocket gophers occupying low lying areas desert their winter homes in favor of drier ground (Thorn 1978:182). They will frequently, but not always, return to the home range occupied the previous season (Ingles 1952:89). Monitoring of pocket gopher dispersal patterns over a three year period in the Sierra Nevada Mountains in California found the longest distance an adult male pocket gopher moved to a new territory to be 27 m and for juvenile pocket gophers 120 m (Ingles 1952).

Population densities as high as 200 pocket gophers per hectare have been reported in environments with abundant forage (Huntly and Inouye 1988). Alpine and sub-alpine regions have lower population densities. In Black Mesa, Colorado, pocket gopher density ranged from 10 to 91 individuals per hectare (Beck 1965), 40 to 46 in the Front Range of Colorado (Thorn 1978), and 10 to 40 in the Wasatch Plateau of Utah (Ellison 1946).

Food and Foraging Tunnels

Pocket gophers feed underground on the roots and stems of grasses and forbs (Huntly and Inouye 1988). The nutritional demand of burrowing compels pocket gophers to consume large quantities of vegetation, which greatly affects the distribution, abundance, and composition of plant communities (Ellison 1946; Huntly and Inouye 1988; Sherrod and Seastedt 2001). While pocket gophers will eat both grasses and forbs, in montane environments forbs account for over 90% of food consumed (Beck 1965:8). Forbs in alpine settings may be preferred because they are widely dispersed and have a large amount of subsurface biomass (Sherrod et al. 2005:585).

The network of foraging tunnels radiating from the den chamber run parallel to the ground surface at the depth of root growth. Generally, tunnels are between 10 and 30 centimeters below the surface (cmbs), although they can extend up to two meters deep (Beck 1965; Bocek 1986). The Northern Pocket Gopher has a broad range in tunnel depth, from 8 to 152 cmbs. Research has shown rocky soil limits the depth of tunneling to 3.6 to 7.9 cmbs (Thorn 1978:184). In places with snow cover, tunnels created during the winter can be seen on the ground surface (Figure 2.4). Tunneling compacts the soil upward into the overlying snow, forming tube-shaped casts of sediment where the pocket gopher traveled. At snowmelt, these long cylindrical casts of sediment become exposed (Ellison 1948; Ingles 1949, 1952).

Figure 2.4. Evidence of Pocket Gopher Activity at 48PA2874

Three kinds of pocket gopher activity at 48PA2874:

a) Sediment ejected from burrowing and degrading soil cores, areas of former occupation would frequently be reused seasonally
b) Soil cores form only under snow cover this was revealed upon sow melt during spring thaw,
c) Mounds of sediment ejected during spring/summer activity.

Photographs by L.C. Todd

Beck (1965) compared burrowing depths in alpine, sub-alpine, and sage-bunchgrass ecotones in Saguache County, Colorado. The deepest burrowing occurred in the lowest elevation zone, the sage-bunchgrass environment. The shallowest burrows were located in the alpine areas, the highest elevations (Table 2.1). The elevation of the current research area (3100 m) is between the sub-alpine and shrub-bunchgrass environmental zones.

Table 2.1. *Thomomys talpoides:*
Burrow Depth by Ecotone in Saguache Co, Colorado (Beck 1965)

Thomomys talpoides	Alpine (3810m)	Sub Alpine (3500m)	Shrub-bunchgrass (2834m)
Average Burrowing Depth	34 cm	41 cm	69 – 94 cm

Individual tunnels can be as long as 100 m with diameters between 5 and 25 cm, depending on the size of the pocket gopher (Gabet et al. 2003). The areal extent of tunnel systems varies from 20 to 200 m^2 per gopher (Beck 1965:5; Bocek 1986). In alpine environments, Thorn (1978:181) reports a pocket gopher territory typically spans 56 m^2. Beck's research in south-central Colorado showed territory size varied greatly, between 7.4 and 187.3 m^2 (Beck 1965).

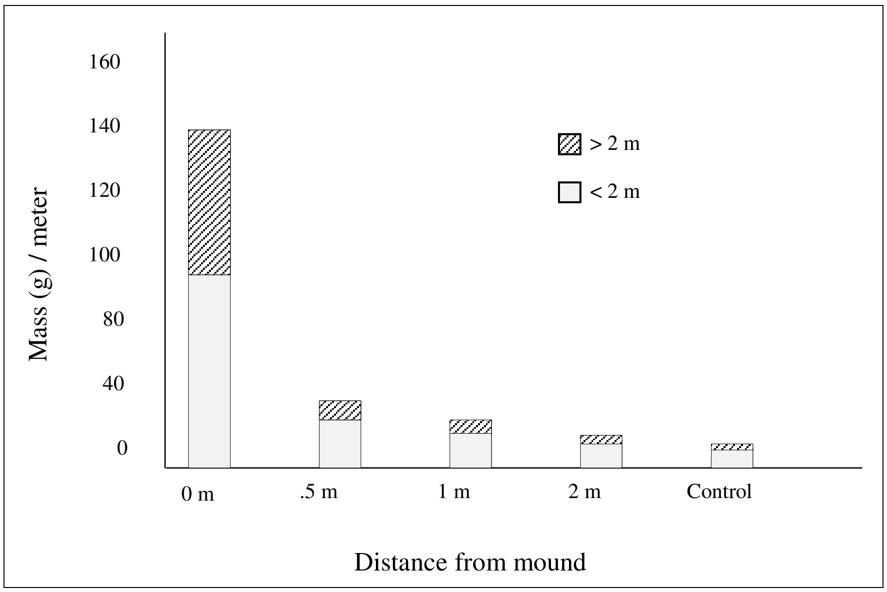
Sediment Disturbance and Erosion

Through their excavation of underground tunnels and deposition of sediment on the ground surface, pocket gophers can have a significant impact on the landscape. Long-term research conducted in the Colorado Rocky Mountains found *Thomomys talpoides* transport 3.9 to 5.8 metric tons of sediment per hectare per year to the surface (Thorn 1978:186). In the same study area, researchers found particularly prolific pocket gophers could transport 48,000 cm^3 (48 liters) of sediment to the surface in a single day (Litaor et al. 1996:38). In Minnesota, *Thomomys talpoides* creates on average 2.86 mounds per gopher per day (Mielke 1977). Areas with substantial occupations can completely rework surface sediment in three to five years (Bocek 1986:590). In addition to displacing massive amounts of sediment, pocket gophers transport clasts as large as their tunnels, typically around 5 cm in diameter (Bocek 1986:591). Pocket gopher research conducted in Gunnison County, Colorado, showed gophers avoided rocks larger than 2.5 cm in diameter (Morris 1968:6). Pocket gopher activity resulted in size-sorting of clasts, with mounds containing more rocks between 0.6 and 2.5 cm in diameter than the adjacent surface sediment (Morris 1968:391).

Wind, water, and gravity redistribute sediment deposited on the surface by pocket gophers (Sherrod and Seastedt 2001). Over time, these processes can bury archaeological deposits. Fine particulate matter is more easily eroded than larger particles, which causes mounds and soil casts to contain a greater percent of sand and less silt and clay relative to the surrounding sediment (Thorne 1978:185). Where surface openings to burrows are closely spaced, entire burrow systems may be "scoured out" by water runoff (Thorn 1978:184). Researchers at the Niwot Ridge LTER site measured the volume of sediment in fresh pocket gopher mounds and again 1-year later. The average volume of fresh mounds (48,000 cm^3) decreased by ¾ (10,200 cm^3) in a single year (Litaor et al. 1996:38).

In a separate study conducted at Niwot Ridge, soil loss from gopher mounds was monitored in a dry alpine meadow, an environment very similar to 48PA2874 (Sherrod and Seastedt 2001). Sherrod and Seastedt (2001:199) measured soil accumulation at 0 m, 0.5 m, 1 m, and 2 meters downslope of pocket gopher mounds and in non-disturbed control areas. The study showed the amount of sediment eroding from gopher mounds was statistically greater than the control areas at distances up to 0.5 m (Sherrod and Seastedt 2001:201). Beyond 0.5 m, there were, on average, more sediment removed from pocket gopher mounds than control areas, however the difference was not statistically significant (Sherrod and Seastedt 2001:202). Figure 2.5 (Sherrod and Seastedt 2001:203), shows the amount of sediment moved at each distance interval. The figure divides the sediment into two size fractions, particles over 2 mm and under 2 mm. As would be expected, a greater amount of fine material was transported.

Figure 2.5. Erosion of Gopher Mound Sediment at the Niwot Ridge LTER Site
Distance moved and amount of sediment eroding from gopher mounds. Particle size of transported sediment is indicated. Figure adapted from Sherrod and Seastedt (2001:Figure 1a).

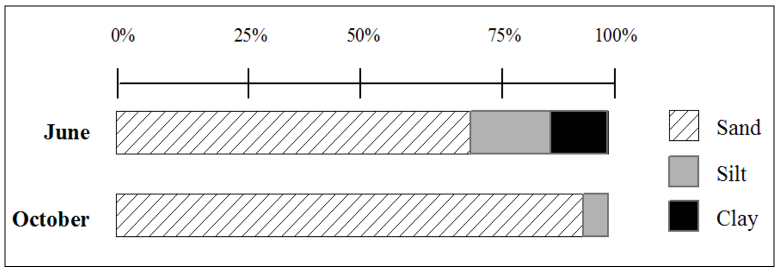


Although the amount of sediment removed from pocket gopher disturbed areas was only significant in the immediate vicinity of the mounds, particle size analysis showed a considerable change in sediment texture (Figure 2.6). In the summer, freshly ejected pocket gopher mound sediment contained approximately 30% silt and clay. By fall, burrows contained no clay and only a small amount of silt could be detected (Sherrod and Seastedt 2001:204).

Topographic Influences on Erosion

The degree of slope affects the intensity of erosion and where sediment is deposited. The movement of sediment displaced by gophers does not simply increase with an increase in slope, as is often assumed (Gabet 2000; Gabet et al. 2003).

Figure 2.6. Seasonal Change of Particle Size in Gopher Mounds at the Niwot Ridge LTER site (Adapted from Sherrod and Seastedt 2001:Figure 2a)



Gabet et al. (2003:266) developed a slope-dependent equation modeling the movement of sediment from gopher mounds. On level ground, pocket gopher mounds form a ring or 'donut' shape around the surface opening of the tunnel. As slope increases the sediment ejected from the tunnel heads downhill, causing an initial increase in sediment flux (Gabet et al. 2003:267). The primary method of transportation at steeper gradients is mechanical processes rather than the physical movement of sediment by pocket gophers (Gabet et al. 2003:267). Sediment flux does not have a steady increase with steeper gradients. Erosion of gopher sediment on hill slopes can be limited by vegetation or other obstructions; particularly by the terraces which form as excavated sediment accumulates around the surface opening of the tunnel (Gabet et al. 2003:267).

Pocket Gophers and Archaeology

Current understanding of the affect of pocket gopher activity on cultural material is based on three key studies; Barbara Boceks's (1986, 1992) experimental work at the Jasper Ridge site, Donald Johnson's (1989) examination of stone zone formation, and Jon Erlandson's (1984) identification of bimodal patterning in artifact distribution. The next section describes and discusses the findings of these three research projects.

Artifact Transportation: Vertical and Horizontal Displacement

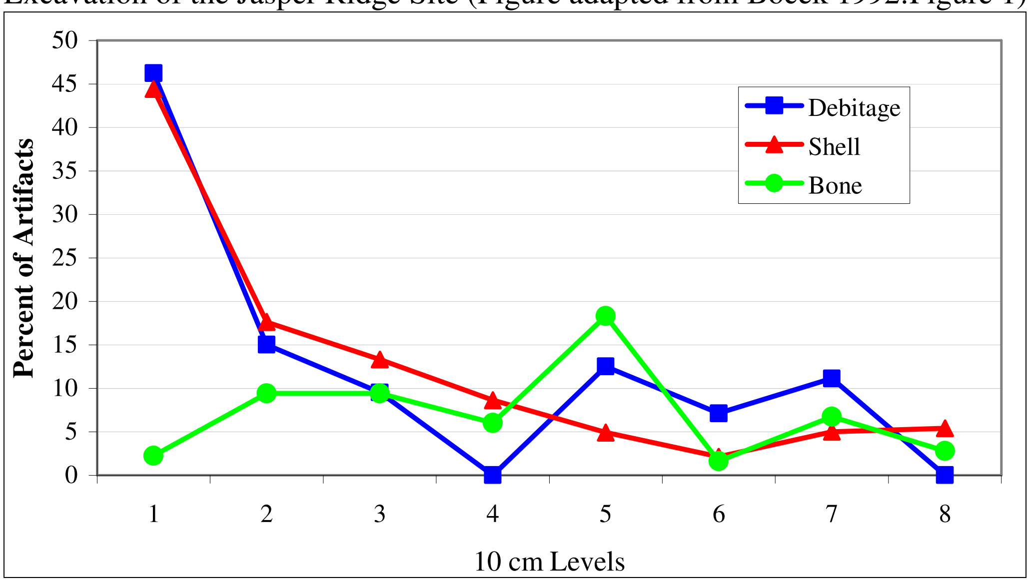
Bocek (1986, 1992) investigated the degree of vertical and horizontal artifact displacement caused by rodent activity in the Santa Cruz Mountains in California. The Jasper Ridge Site (CA-SMa-204) is located on a grassy alluvial terrace that supports a substantial gopher population. The site is a short-term camp dating to around 900A.D. (Bocek 1986: 592). Excavation showed artifacts were size stratified at two distinct depths. Smaller (0.6 - 5 cm) pieces of debitage, fire-cracked rock, and culturally unmodified rock were concentrated near the surface while larger (≥ 5 cm) materials were clustered around 40 cmbs. Artifact frequency decreased dramatically below 50 cm.

Bocek (1986, 1992) proposed the segregation of material by size resulted from gopher activity. Since pocket gophers are unable to transport objects larger than the diameter of their tunnels (around 5 cm) they burrow around and beneath larger objects (Bocek 1986:591). As a result, the larger clasts sink to the maximum depth of gopher activity and the smaller clasts are moved upward. This produces a size stratification with lithic materials less than 5 cm in diameter near the surface and larger materials between 30 and 60 cm beneath the surface. Although lithic artifacts displayed this distribution, shell artifacts had a different pattern. Shells, consisting mostly of bivalves, displayed a unimodal distribution concentrated at 40 - 50 cmbs. Bocek (1986:597) proposed the extremely low-density, thin, flat shells were transported by different mechanisms from the larger and heavier objects (1986:597). Of the three types of shells found at the site, higher density shell acted more similar to lithic artifacts and occurred more frequently than low density shell in the upper excavation levels. Transport of artifacts in gopher - disturbed areas is impacted by both the size and density of material (Bocek 1986:597).

Seven years after the initial research at the Jasper Ridge, Bocek (1992) returned to investigate subsequent gopher disturbance. During the first excavation all material larger than 0.6 cm was collected and the units were backfilled with sieved sediment. Therefore it could be assumed upon re-excavation that any objects larger than about 0.6 cm had been introduced into the unit, possibly by pocket gophers. As mentioned above, the objects transported by pocket gophers are constrained by tunnel diameter and should be no greater than five centimeter in maximum length. As the majority of gopher activity occurs in the first 30 cmbs, a greater number of artifacts should be found in the upper 30 cm than in deeper layers.

Re-excavation revealed that 8% of the cultural material found during the first excavation had been introduced into the unit; a process they attributed to gopher activity (Figure 2.7). The vast majority of artifacts were smaller than 1.8 cm. In fact, only a single flake larger than 3.5 cm was recovered. This artifact was found in the first 10 cm of excavated sediment (Bocek 1992:264). No new material had been deposited on the surface of the unit. In Level 1 (0 to 10 cmbs), the highest proportion (41%) of the original amount of cultural material had been transported into the unit. At greater depths the amount of cultural material introduced into the unit decreases, likely due to the lack of gopher activity. The only exception occurred from Level 6 (50 - 60 cmbs) to Level 7 (60 - 70 cmbs) where the percent of material increased 2.9%. When comparing artifact size distributions from the 1981 and 1988 excavations, "frequency distributions suggest that small-sized materials are gradually dispersed throughout the zone of maximum rodent activity as soil disturbance increases through repeated burrowing" (Bocek 1992:267).

Figure 2.7. Percent of New Artifacts Introduced into Units Seven Years after Initial Excavation of the Jasper Ridge Site (Figure adapted from Bocek 1992:Figure 1)



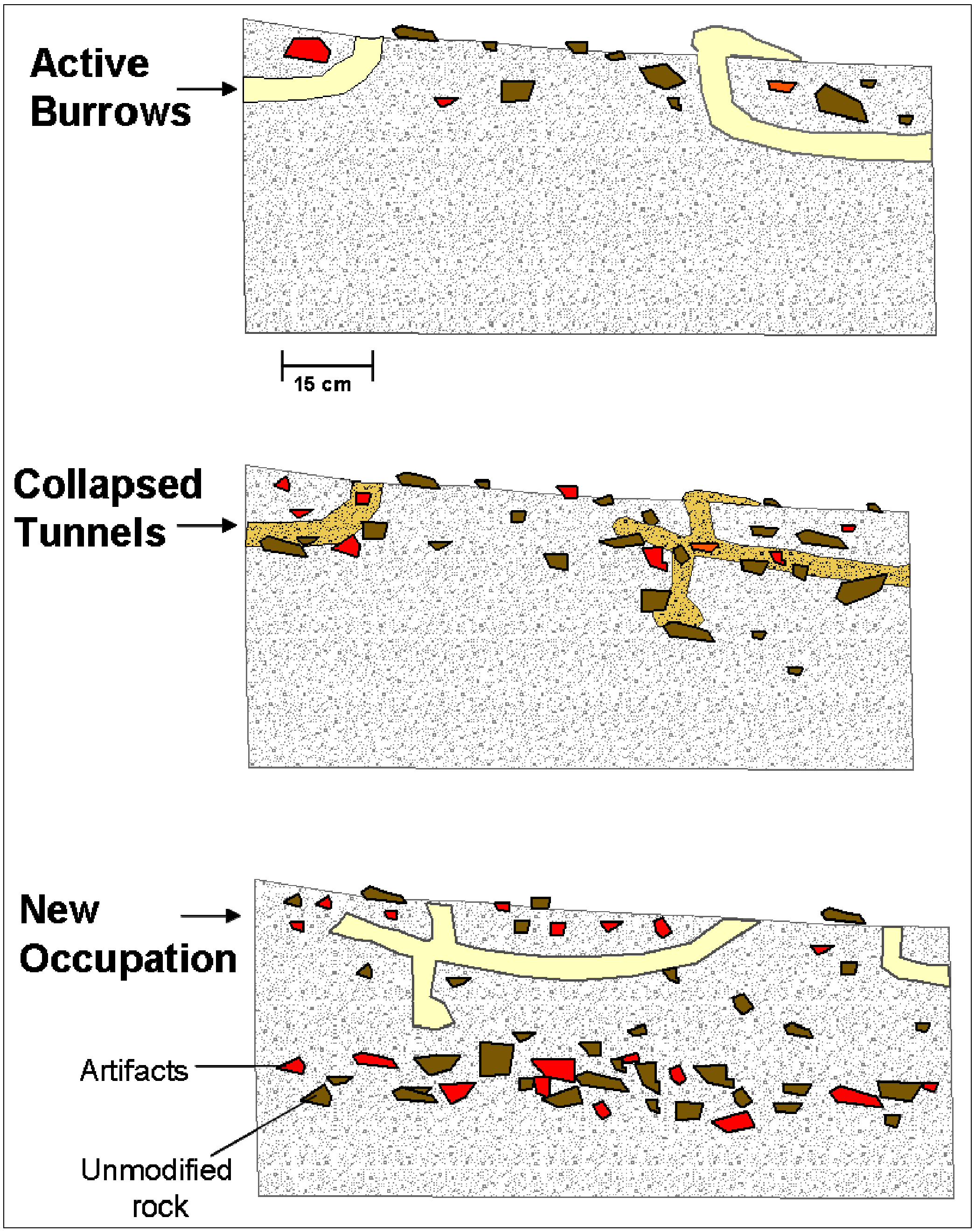
This study is particularly significant because, in the past, archaeologists have associated gopher disturbance primarily with vertical, not horizontal disturbance of artifacts (Bocek 1986). Yet Bocek's (1992) research clearly indicates rodent activity can expand the area of a site and impact the density of artifacts. Bocek calculated it would take only 88 years for gopher activity to completely 'restock' the cultural material to the excavated unit. In the almost one-thousand years since the prehistoric occupation of

Jasper Ridge, Bocek determined the artifacts in the unit could have been recycled 11 times (Bocek 1992:268).

Geomorphic Impacts: The Formation of 'Stone Zones'

Donald Johnson (1989) investigated the impact of pocket gopher activity on stratigraphy at the Signorelli Ranch site near the Vandenberg-Lompoc area of California. The site is located on a gravelly colluvial apron inundated with both abandoned and active pocket gopher mounds. A road cut at the site exposed a soil profile consisting of a homogenous biomantle of dark sediment overlaying a discrete pavement of randomly oriented natural stones and archaeological artifacts all with lengths ≥ 6 cm. The layer of stone varied between 30 and 50 cm thick at a depth ranging from 25 to 60 cm below the surface. Archaeological artifacts of similar size were incorporated in the layer of natural rock. Particle size and chemical analysis of mounds and soil overlying the stone zone showed the sediment was indistinguishable (Johnson 1989:370). The accumulation of larger clasts corresponds to the size of material that gophers are unable to transport and to the depth of burrowing. Johnson attributed the soil profile seen at the Signorelli Ranch site to the gradual sinking of the larger materials that gophers avoid while burrowing (Figure 2.8). Gophers typically go around or beneath larger objects, which forms voids that large clasts overtime descend into (Johnson 1989:372). He termed these non-cultural features 'stone zones.' The notion that gophers were not transporting clasts of a certain size was supported by the lack of material larger than 6 cm in gopher mound sediment (Johnson 1989:376). This study is important as it demonstrates that concentrations of subsurface archaeological material may result biomechanical processes and not human activity.

Figure 2.8. Formation of Stone Zones Proposed by Johnson (1989)



Gophers and Stratigraphic Integrity: Bimodal Artifact Distribution

The impact of pocket gopher activity on the vertical distribution of artifacts was studied by Erlandson (1984) at a short-term, single component prehistoric site in the foothills of Santa Barbara, California. Prehistoric artifacts found during excavation included temporally diagnostic shell beads, bone, and lithic debris. A small number of historic artifacts and sediment that had been soaked in motor oil were present in some of the units. The intense mixing of sediment at the site, identified by the presence of krotivina, made distinguishing in-situ deposits impossible (Erlandson 1984:785).

Artifact frequency by depth had a weakly bimodal distribution (Erlandson 1984:787). The largest peak occurred at either 10 to 20 cmbs or 20 to 30 cmbs, depending on the location of the excavation unit. A dramatic decline in artifact frequency occurred from 30 to 50 cmbs depth followed by a second, less dramatic peak or "distinctive flattening in the declining curve" (Erlandson 1984:787). To determine if the bimodal distribution in prehistoric artifact frequency resulted from post depositional disturbance or multiple occupation events, Erlandson examined the distribution of the modern oil-inundated sediment. The oil-soaked profiles had the same bimodal distribution as the prehistoric artifacts, strongly supporting the idea taphonomic processes were affecting the distribution of archaeological material.

Studies on *Thomomys bottae*, the species present in Erlandson's research area, show tunneling occurs at 15 to 20 cm and burrows at 50-55 cmbs. The distribution of cultural material at the site was attributed to the infilling and collapse of abandoned tunnels and dens (Erlandson 1984:788). Assuming this was occurring at the site, Erlandson calculated that in the 500 years separating the prehistoric and historic occupations at the site, the average rate of artifact redistribution was 5% per 100 years (1984:789).

Pocket Gophers and Archaeology: Summary

The studies discussed above show the significant effect pocket gopher activity can have on the distribution of archaeological material. Pocket gophers are most often associated with the homogenization of soil horizons and the mixing of stratigraphic sequences. Bocek's research (1992) showed artifacts disturbed by burrowing are not limited only to vertical relocation. Pocket gopher activity can transport artifacts laterally; a notion not extensively considered prior to her work at Jasper Ridge. Horizontal movement can increase the spatial extent of a site; and because pocket gophers typically only move material less than 5 cm in length, lateral transport results in decreased density of a particular size-class of artifacts.

The vertical sorting of artifacts by size within the soil profile was addressed by both Bocek (1986) and Johnson (1989). Both studies found pocket gopher activity dispersed smaller artifacts within a homogenized matrix throughout the burrowing zone. Larger artifacts tended to accumulate at the maximum depth of pocket gopher activity, forming what Johnson (1989) refers to as a 'stone zone' (Figure 2.8). Stone zone formation was linked to one of two processes. One, large surface clasts may become buried by sediment and by small clasts that pocket gophers transport to the ground surface (Balek 2002: 43) or by the gradual sinking of larger clasts that pocket gophers burrow around (Bocek 1984; Johnson 1989). Erlandson (1984) demonstrated how a bimodal distribution of sub-surface artifacts could result from the infilling of abandoned tunnels. Two stratigraphically distinct concentrations, such as those encountered by Erlandson (1984), Johnson (1989), and Bocek (1986, 1992) could easily be mistaken as an indicator of human created features or multiple occupations.

Studies evaluating the impact of pocket gopher activity on archaeological material show there is a great potential to misinterpret natural phenomenon as human behavior. This project aims to build upon previous studies of pocket gophers occupying archaeological sites and to develop ways to identify the tell-tale signs of gopher activity. The following chapter describes how pocket gopher occupation was documented at 48PA2874, the analysis conducted to explore patterns in the horizontal and vertical distribution of artifacts, and the methods used to evaluate the impact of gopher disturbed sediment on site formation processes.

CHAPTER 3

RESEARCH METHODS AND DATA

Site 48PA2874 was discovered by Dr. Lawrence Todd in the summer of 2004 during a recreational hike. Colorado State University archaeological field school students documented the site in 2005 and returned to conduct additional research in 2006. 48PA2874 is distinguished from other local sites by the quantity and density of lithic debris, diversity of tool types, range of chronologically diagnostic projectile points, and the presence of spatially discrete concentrations of artifacts. Temporally diagnostic projectile points found on the surface of the site indicate human presence as early as the Late Paleoindian period, approximately 9,000 years before present with episodes of use extending into the Late Prehistoric, within the last 1000 years. Fieldwork had two objectives: 1) to determine if 48PA2874 contained buried cultural deposits; and 2) to investigate the impact of pocket gopher activity on artifact distribution.

This chapter outlines the methods used to record surface artifacts, conduct test excavation, and document pocket gopher activity. This is followed by a discussion of the artifact assemblage at 48PA2874, the results of the test excavation, and data recorded on pocket gopher burrows.

Research Methods

Documentation of 48PA2874

Artifacts at 48PA2874 were identified using a non-systematic survey strategy known as noodling. Noodling refers to the focused examination of the area surrounding an artifact. Standardized artifact attributes were entered into an Excel spreadsheet using a personal digital assistant (PDA). Location information for each artifact was collected with a Wide Area Augmentation System (WAAS)-enabled handheld Garmin Rino 110 GPS (± 5 meter accuracy). Attributes documented on each artifact include type, raw material, dimensions, color, presence of inclusions, heat modification, and percent of dorsal cortex. In 2005 the primary and secondary color of an artifact and the portion of the flake present (complete, platform, no platform) were noted. Documentation of these two characteristics was discarded in 2006 in an effort to increase the rate of artifact recordation. In both field seasons, artifacts were divided into eight broad artifact types and then sub-divided into more specific categories. The eight general artifacts types are: flake, angular debris, nodule/cobble, core, awl, biface, scraper, and projectile point. Flakes and angular debris were further identified as having no edge modification, edge modification of undetermined origin (i.e., resulting from either natural processes or human behavior), or having clear, human worked edges. Bifaces were classified into five stages representing a continuum in the production sequence; Stage 1 being initial reduction to Stage 5, a finished tool. Scrapers were subdivided into side, end, or general/undefined scraper categories. Nodules were identified as tested, worked, or complete cobbles. Cobbles were defined as an unbroken stone of a type of raw material suitable for knapping not naturally occurring at the site. The amount of cortex on an artifact was described as 0%, 1 - 10%, 10 - 25%, 25 - 50%, 50 - 75%, or 75 - 100% coverage on the dorsal surface. When present, the type of heat modification was recorded (crazing, potliding, thermal fracturing, or multiple types). Projectile points and most tools were photographed and GPSed with a Trimble GeoXT (sub-meter differentially corrected accuracy). Additional measurements recorded on projectile points include blade length, neck width, stem length, side-notch depth, and basal notch depth. Other then the temporary collection of obsidian for geochemical sourcing (Bohn 2007), no surface artifacts were collected. Epoxy molds were taken of chronological diagnostic projectile points and other notable artifacts.

Test Excavation Methods

Test excavation was conducted at 48PA2874 to determine if buried cultural material was present and to gain a better understanding of site formation processes. It was suspected that loose sediment from pocket gopher mounds was eroding into small alpine sag ponds located at the site, creating buried archaeological deposits. The area chosen for test excavation was a centrally located sag pond surrounded by pocket gopher activity and a moderate to high density of surface artifacts.

Four 1 by 1 m test units were excavated at 48PA2874. Units were laid out in an alpha-numeric grid system that divided the site area into 5 by 5 m blocks (Figure 3.1). East-west trending grid lines were assigned letters in alphabetic order and north-south grid lines were sequentially numbered. Each 5 by 5 m block was identified by the corresponding letter-number combination. The blocks were than sub-divided into 1 by 1 m units, for a total of 25 units per block. The units were sequentially numbered, beginning in the southwest corner and moving north, then east at the end of each row. This provided each 1 by 1 m unit with a unique identification, for example A 1 - 1.

Figure 3.1. Example of the Excavation Grid Layout

A 1 -5	A 1 – 6	A 1 - 15	A 1 – 16	A 1 - 25
A 1 -4	A 1 – 7	A 1 – 14	A 1 - 17	A 1 – 24
A 1 – 3	A 1 - 8	A 1 – 13	A 1 - 18	A 1 – 23
A 1 -2	A 1 - 9	A 1 – 12	A 1 - 19	A 1 – 22
A 1 -1	A 1 - 10	A 1 – 11	A 1 - 20	A 1 – 21

5 m by 5 m
Block A 1

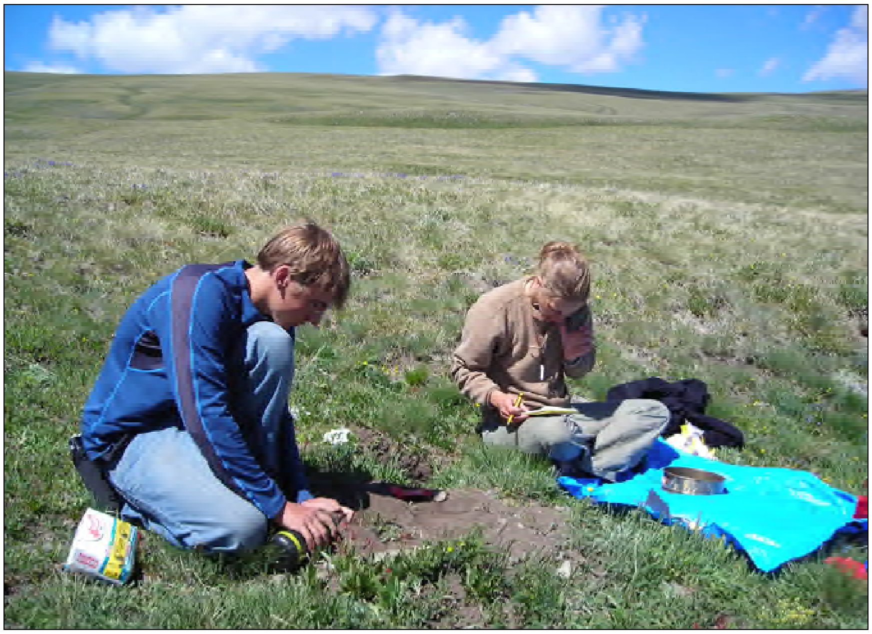
The four 1 by 1 m units were oriented so that two units bordered one another on the north/south axis, forming two 1 by 2 m test excavation areas. One 1 by 2 m excavation area (units U27-16, U27-17) was located at the edge of the sag pond. The other two units (T26-6, T26-7) were placed on a gentle slope leading into the pond. Units were excavated and cultural material collected in five centimeter vertical intervals or levels. Artifacts and charcoal larger than one centimeter were mapped in-situ with a Sokkia Set 4B EDM (electromagnetic distance measurement). Sediment was screened by level with a 1/8th inch wire mesh screen. Artifacts were documented with the same methods used on surface material. Charcoal samples larger than one centimeter encountered during screening were also collected. When abundant, only a representative sample of charcoal per level was collected.

Eight sediment samples were collected from the test excavation units. Five samples were collected from U27-16 (pond unit) at depths ranging from 1 cmbs to 115 cmbs. Three samples were collected from T26-17, the excavation unit located up-slope of the pond. Color was identified for each sample using Munsell soil color charts (Color 1975). Particle size analysis was conducted by Naomi Ollie, a former Colorado State University (CSU) graduate student, at the CSU Soil, Water and Plant Testing Laboratory Soils Laboratory using the hydrometer method. This method uses the settling rates of sediment in an aqueous solution to determine the proportion of sand (particles measuring 2 – 0.05 mm), silt (0.05 – 0.002 mm), and clay (<0.002 mm) in a sample. Three charcoal samples from test excavation unit U17-17 were sent to Beta Analytical for radiocarbon analysis (Beta - 221329, Beta - 221330, Beta - 221331).

Pocket Gopher Data Collection

The effect of pocket gophers on archaeological material and site formation at 48PA2874 was explored through the documentation of surficial evidence of pocket gopher activity in a one-hectare sample area surrounding a small sag pond (Figure 3.2). The study used these data to identify topographic controls on burrow placement, examine the influence of pocket gophers on artifact distribution, and evaluate the amount of erosion occurring from disturbed sediment.

Figure 3.2. Pocket Gopher Documentation at 48PA2874



Photograph by L.C. Todd

Pocket gopher activity was identified through pedestrian survey that began at, and radiated out from, the excavation units located in the dry sag pond. Pocket gopher occupation was indicated by the presence of small mounds of sediment and soil casts. Soil casts form during winter months and pocket gopher data were collected in June, therefore researchers were able to classify gopher activity as active (mounds) or inactive (soil casts). The presence of cobwebs or extremely dry, deflated soil on some mounds suggested they were not in use at the time of recording. To determine if mounds were currently active, the sediment, after being analyzed, was placed back into the burrow opening. The burrow was subsequently monitored for freshly ejected sediment as an indication of activity. Burrow locations were mapped using an EDM total station and the following characteristics were documented: the type of burrow (mound or soil cast), volume of disturbed sediment, volume of disturbed rock, length and width of the mound or the length of the tunnels, and size of burrow opening. The sediment disturbed by pocket gophers was sieved through 4.76 mm (0.187 in) wire mesh screen. Artifacts encountered were collected and analyzed using the same methods employed for surface and subsurface test excavation artifacts. In addition, sediment and rock samples were collected from each burrow. Non-culturally modified rocks with lengths greater than 5 cm were documented but not collected.

To determine the size distribution of clasts within gopher-disturbed sediment, rock samples were sorted by size using an Al-Sci Sieve/Gravelometer. The gravelometer measures clasts with lengths between 4 mm and 128 mm, at intervals ranging between 1.7 mm and 10mm. Sediment collected from 25 burrows underwent the same particle size analysis as sediment from test excavation units. Artifacts collected from gopher-disturbed sediment were analyzed using the method described for excavation and site surface artifacts.

Geospatial Analysis of Gopher Burrows

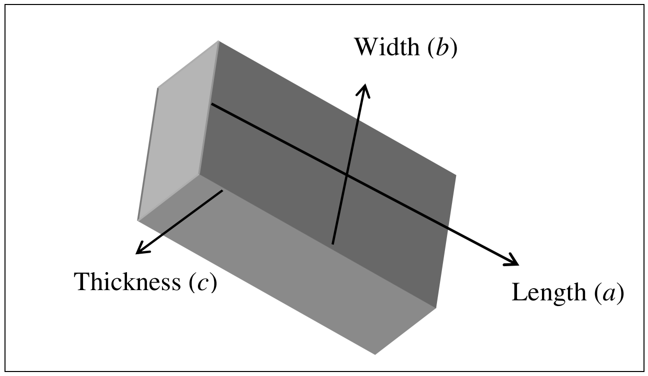
Topographic controls on burrow placement were explored utilizing GIS software ESRI ArcGIS 9.1 and 9.2. The location of burrows and their associated attributes, including type (mound or soil core), occupation status, sediment volume, particle size distribution, non-cultural stone, and artifacts, were examined in relation to elevation, aspect, and slope. Slope and aspect were calculated using high resolution elevation data collected during fieldwork.

A separate analysis of data from burrows located within the catchment area was conducted to examine erosion specifically within the pond. The hydrologic boundaries of the pond were determined using Geographic Information Systems (GIS) software ArcGIS 9.1. The Spatial Analyst Flow Direction Hydrology function in ArcGIS 9.1 calculates the direction surface water travels based on elevation data. Using a 10-m resolution digital elevation model (DEM) from the US Geological Survey EROS Data Center (http://seamless.usgs.gov 1999), the program identified an area 1880 m^2 (0.188 ha) as the pond catchment.

Statistical Evaluation of Artifact Characteristics

The maximum length of artifacts and multiple shape indices were used to explore patterns and correlations in gopher mound, surface, and subsurface artifacts. The length (a), width (b), and thickness (c) (Figure 3.3) of each artifact was obtained using digital calipers and the measurements applied to equations that quantify the physical features of cultural material. The shaped indices of elongation, flatness, and blockiness/sphericity were calculated using the following ratios b/a, c/b, and $(bc/a^2)^{1/3}$ (Scally and Owens 2005). Axial measurements are correlated with particle weight and therefore can be used as a size index as well as a shape index (Scally and Owens 2005:50). The calculation used to categorize weight is $(a+b+c)^{1/3}$. Normal distribution of the data was determined using Levene's test for equality of variance. Once determined, the appropriate *t* test (parametric/nonparametric) was applied. Tabular data for each statistical test are listed in Appendix B.

Figure 3.3. Axial Measurements Used to Calculate Shape Indices

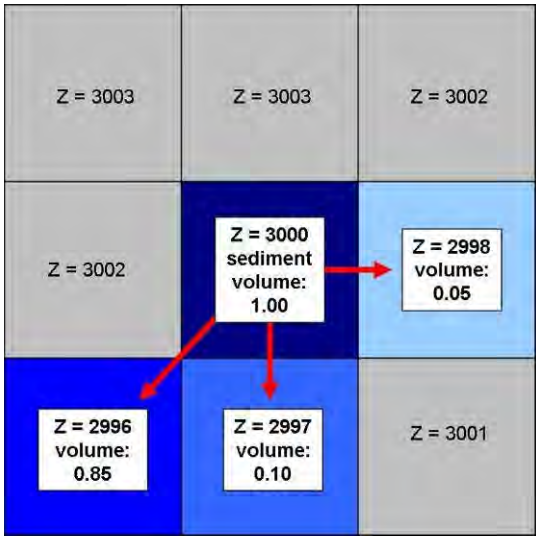


Geographic Information System Erosion Model

A Geographic Information System (GIS)-based erosion model was used to predict the path and amount of erosion occurring from pocket gopher mounds. The program, called the D90 Erosion model, was created by Dr. Denis Dean, a former professor in geospatial science at CSU (Dean 2006). The model determines path of erosion from a given starting point based on elevation data. It is assumed particulate matter will travel the path of least resistance, i.e., downslope. As shown in Figure 3.4, elevation data are in a grid format (raster) where each grid cell represents the elevation of a 0.5 m by 0.5 m area on the ground surface. The starting point, the gopher mound, is linked to a number representing the volume of material available for erosion. If the cell adjacent to the gopher mound is lower in elevation, then a user-defined percentage of sediment is transferred downslope.

The D90 model is a Visual Basic 6 program that reads two ASCII files; one representing the 'source' points (gopher burrows) and one representing elevation data. Both ASCII files were exported from ArcGIS 9.2 using the Raster calculator tool. Once imparted into Visual Basic 6, the D90 program evaluates gopher mound data in

Figure 3.4. The D90 Erosion Model



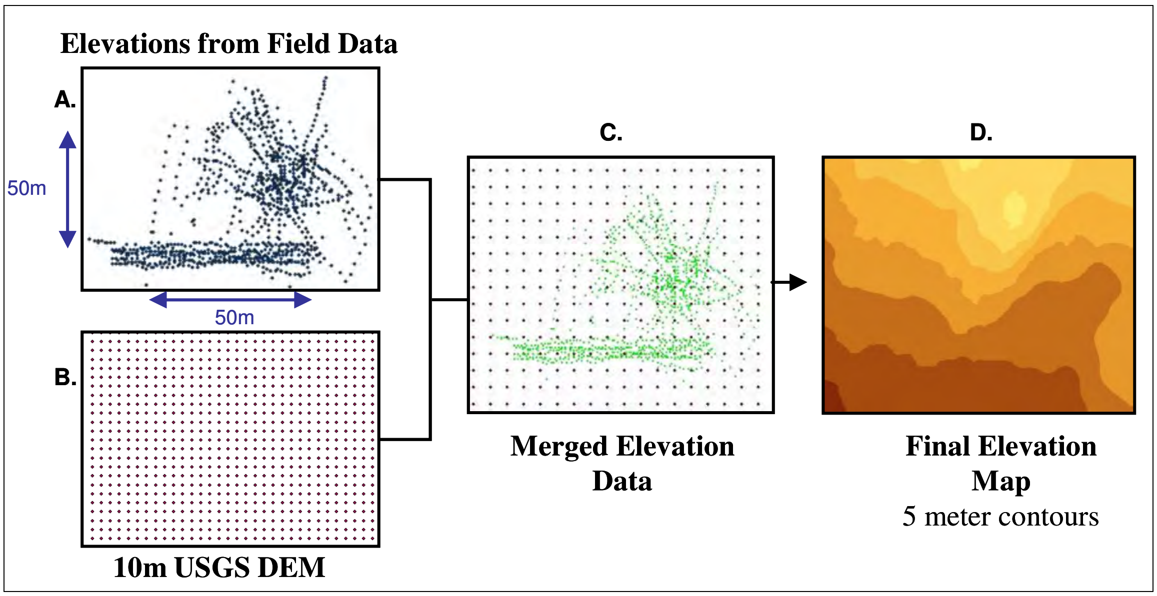
Pocket gopher burrow location data and the associated volume of sediment (1.00) is superimposed on elevation data (Z) and moves a user-specified percent of sediment (0.85, 0.10, 0.05) into adjacent downslope cells. If only two cells bordering the source area are lower in elevation, than the program will move only the portion initially allocated and the remainder stays in the source cell. In the example below if only two cells were lower in elevation than the source cell, then 0.85 and 0.10 would be transported and 0.05 would remain in the source cell.

conjunction with elevation data, moving a user-defined percentage of sediment in a specified number of directions (shown in Figure 3.4). Material is moved only when adjacent elevations are lower than the source area. The percent of sediment moved is ranked, meaning a higher percentage of material will be moved to the lowest elevation, a lower percentage will move to the next lowest elevation and so forth. If sediment moves into an area previously evaluated, the new volume is added to the current volume and the algorithm is re-run. The process per cell is terminated when either there is no more sediment is available to move or no neighboring area has a lower elevation. The model outputs an ASCII database containing the path and volume of material eroding from each gopher mound. The ASCII file is then brought into ArcGIS and turned into a raster database using the Raster Calculator tool.

The model is interpreted as predicting one year of sediment accumulation in a 0.5 by 0.5 m area (the user-determined size of the elevation data grid cell). The predicted path and amount of sedimentation was compared with an estimate of accumulation derived from three radiocarbon dated charcoal samples collected from known depths in test excavation unit U27-17. If the model predicts sediment will be deposited in the location where the radiocarbon sample was obtained, then the amount of sediment predicted to accumulate can be multiplied by the number of years indicated by the radiocarbon date. The resulting value indicates the volume of sediment deposited in a particular 0.25 m^2 area (0.5 m x 0.5 m cell size) in a specified timeframe. If the model is accurate, predicted deposition should approximate the depth at which the radiocarbon sample was collected.

Elevation data used in the model were collected during field work with an EDM. Although 900 points were taken to document topography, as Figure 3.5 shows, the data were not collected in a grid system. This resulted in some gaps in topographic information. To compensate for the 'missing' data, a 10 m digital elevation model (DEM) of the Phelps Mountain 7.5' Quadrangle was downloaded from the USGS (http://seamless.usgs.gov). The 10 m resolution DEM was merged with the field data using the Append function in ArcGIS 9.2. The resulting shapefile was interpolated using the Kriging function. Kriging is commonly used in geospatial science to generate the value of an unknown field by using data from nearby locations. The kriged elevation map, however, did not represent the actual landscape (Figure 3.5 c). Upon further investigation a discrepancy between the DEM and field data vertical datums was discovered. To reduce the elevation difference between corresponding cells in the database, the average of the elevation discrepancy was calculated and the difference (7.6 m) was added to each cell in the USGS data. The databases were then recombined (using the Append function) and re-kriged (using the Kriging function). The output then satisfactorily represented the topography at the site (Figure 3.5).

Figure 3.5. Steps Used to Merge Field-Collected Elevation Data and USGS DEM
A. Location map of points taken in field with EDM, **B**. 10 m USGS Digital Elevation Map, **C.** Map of merged data points, **D**. Final elevation map used in analysis (lightest areas=lowest elevation, sag pond upper right, ridge trending southwest-northeast)



Gopher burrow information input into in the model consisted of location data, the extent of areal coverage per mound, and the volume of disturbed sediment. Since fines are more likely to be redistributed than sand, only a portion of the sediment volume was used to determine accumulation. The average amount of silt and clay in gopher mounds (determined through particle size analysis) was approximately 50 %, therefore half the volume recorded per gopher burrow was used in calculations.

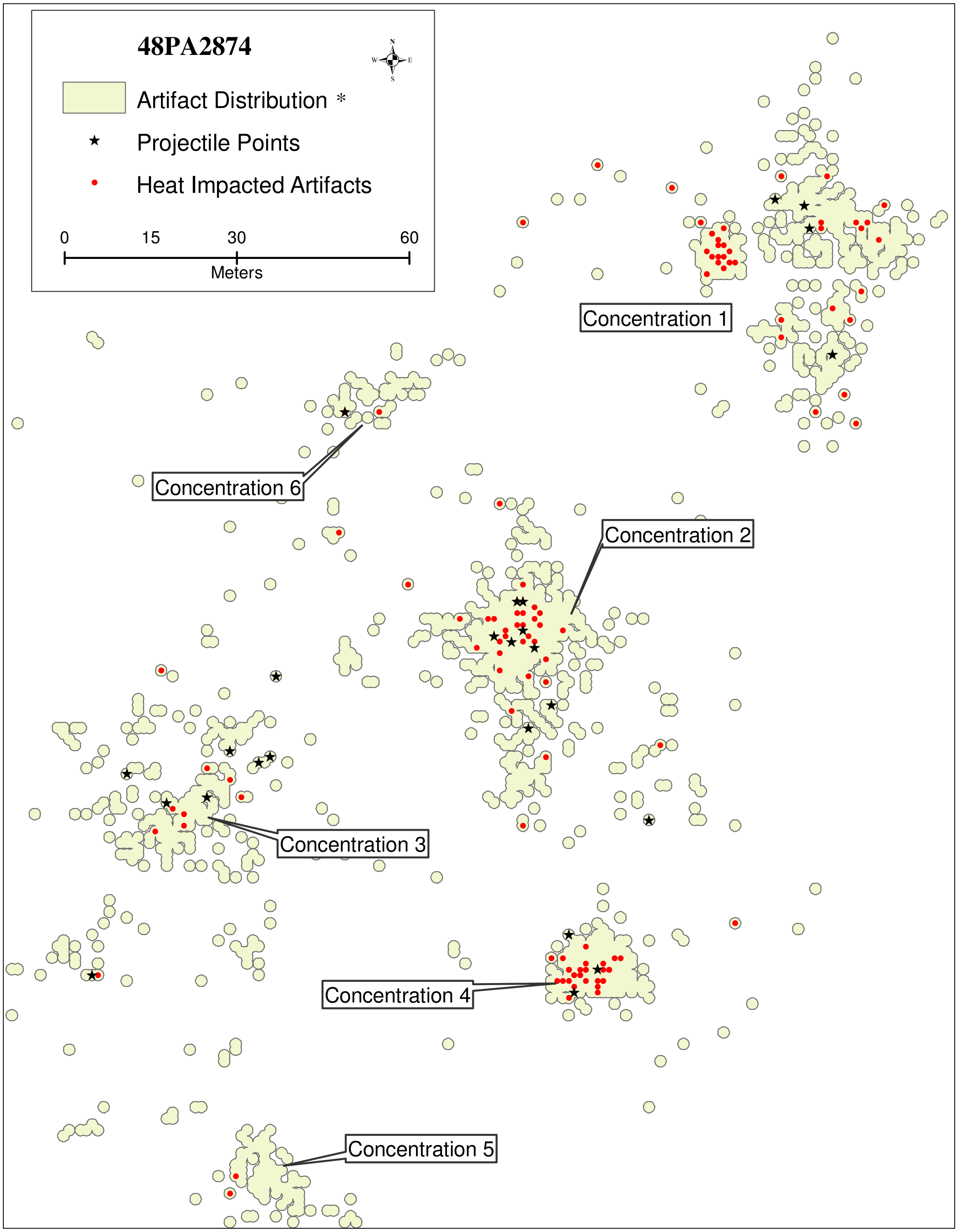
Results of Data Collection

48PA2874: Artifact Assemblage

Over 2,470 artifacts were recorded at the site in an area covering approximately 2.8-hectares. The site is significantly larger and contains a greater quantity and diversity of artifacts than other sites in the vicinity. There are six discrete concentrations of lithic material interspersed with a sparse scatter of debris (Figure 3.6). Three of the concentrations have distinct clusters of heat-altered lithic material, which may indicate the presence of a hearth. A brief description of the site is provided below and additional data are provided in Appendix A. Artifact Concentration 2 is addressed in greater detail as test excavation and pocket gopher documentation occurred within this concentration. A full description of the site is provided in Appendix A.

The artifact assemblage is dominated by flakes and angular debris (97%, n=2385) (Table 3.1). Tools (worked flakes, bifaces, awls, scrapers, and projectile points) comprise 3% (n=75) of the artifacts at the site, nodules and cores make up 0.5% (n=11). Cortex was present on only 3% (n=77) of artifacts. When present, artifacts with 50% or more cortex account for less than one percent of the assemblage (n=16). The lack of artifacts with cortex, the small number of cores, and the absence of an on-site raw material source indicates later stages of tool production rather than initial reduction were occurring at the site.

Figure 3.6. Distribution of Artifacts at 48PA2874



*1 meter buffer around artifacts (n= 2471)

Table 3.1. Summary of Surface Artifacts at 48PA2874

Artifact Types		
Artifact Type	**Count**	**Percent**
Flake	1806	73.1
Worked Flake	16	.6
Edge Damage Flake	463	18.7
Angular Debris	116	4.7
Projectile Point	26	1.1
Biface	20	.8
Scraper	10	.4
Awl	3	.1
Core	4	.2
Nodules	7	.3
Total	**2471**	**100**

Projectile Point Types		
Time Period	**Count**	**%**
Paleoindian	2	8%
Early Archaic	2	8%
Middle Archaic	4	15%
Late Archaic	6	23%
Archaic	4	15%
Late Prehistoric	2	8%
Unidentifiable	6	23%
Total	**26**	**100**

A wide variety of raw material types were found at the site (Table 3.2). Unfortunately much of it (67%) consisted of chert that could not be visually identified by field crews as either local or exotic because similar specimens occur in multiple locations. Artifacts from local raw material make up 21% of the assemblage, non-local material 11%. The high proportion of unknown sources makes inferring information such as preferred tool stone or mobility patterns from these data impossible.

Bohn (2007) analyzed the source of obsidian artifacts throughout the GRSLE project area, including 12 samples from 48PA2874. Obsidian at the site was sourced to three areas, 75% was from Obsidian Cliff located 140 km (87 miles) northwest of the project area, 17% from Teton Pass 142 km (88 miles) west/southwest, and 8% from Park Point, the closest source area, 87 km (54 miles) northwest (Bohn 2007).

As mentioned above, there were six discrete concentrations of lithic debris at the site; three of which had clusters of heat impacted artifacts (Figure 3.6). Although no fire-cracked rock was found, it is likely the fire affected clusters of chipped stone represent the remains of a hearth.

Table 3.2. Raw Material Types at 48PA2874

LOCAL			NON-LOCAL		
Material Type	**Count**	**Percent**	**Material Type**	**Count**	**Percent**
Chalcedony	249	10.1	Quartzite	206	8.3
Mudstone	214	8.7	Obsidian	42	1.7
Petrified Wood	41	1.7	Morrison For. Quartzite	27	1.1
Irish Rock Chert	6	.2	Phosphoria	2	0.1
Volcanic/Basalt	5	.2	Porecelanite	1	0.05
Madison For. Chert	3	0.1	**Total Non-Local**	**287**	**11.3%**
Dollar Mountain Chert	1	0.05	**UNKNOWN**		
Total Local	**519**	**21%**	Chert	1674	67.7
**Toolstone "local" if located in Upper Greybull watershed.*			**Total Unknown**	**1674**	**67.7%**

Concentration 2 surrounds the pond where pocket gopher documentation and test excavation was conducted. Over 800 artifacts were found in approximately 600 m², including eight projectile points, seven bifaces, one core, three worked flakes, five scrapers, and two nodules. The only two projectile points dating to the Paleoindian period at the site are located in Concentration 2. In addition, two Middle Archaic, two Late Archaic, one general Archaic, and one temporally unidentifiable project point were found. The distribution of tools displays an interesting pattern. The four projectile points dating to the Archaic period are clustered in a 10 m² area with the Middle Archaic points lying directly beside one another. With the exception of one Paleoindian point and the unidentifiable projectile point, all projectile points are located within the cluster of heat affected artifacts. However, none of the projectile points have any indication of heat exposure. Other tools contained in the cluster of heat impacted artifacts are three bifaces, four scrapers, three worked flakes, and one nodule. Of these, only one tool, a worked flake, shows evidence of heat exposure.

The extent of 48PA2874, the density of lithic debris, the diversity of tools and raw material, and internal spatial patterning of artifacts suggest a range of activities were occurring at the site. Temporally diagnostic artifacts indicate the site was used as early as

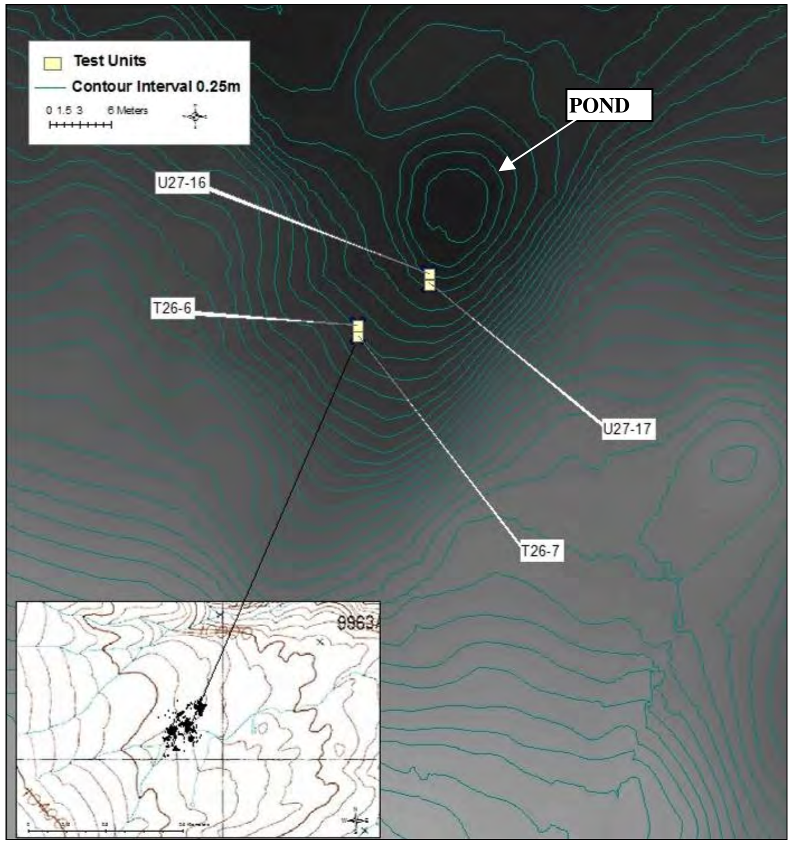
9,000 years before present through the Late Prehistoric period. Clusters of heat impacted artifacts surrounded by debitage and tools suggest areas of focused activity centered around a hearth; which may be associated with more than brief instances of opportunistic hunting.

Test Excavation Data

Four 1 m by 1 m test excavation units were placed within Concentration 2 to determine the presence of buried archaeological deposits and to explore biophysical interactions affecting site formation (Figure 3.7). Taphonomic processes at a site-specific scale were analyzed through the comparison of sediment properties and the physical characteristics of subsurface and surface artifacts. Landscape change occurring at a broad spatial scale is addressed through the examination of soil in the test excavation units. The following section summarizes the results of test excavation and explores general trends in the data. Additional information, including a level-by level narrative for each test unit is provided in Appendix B.

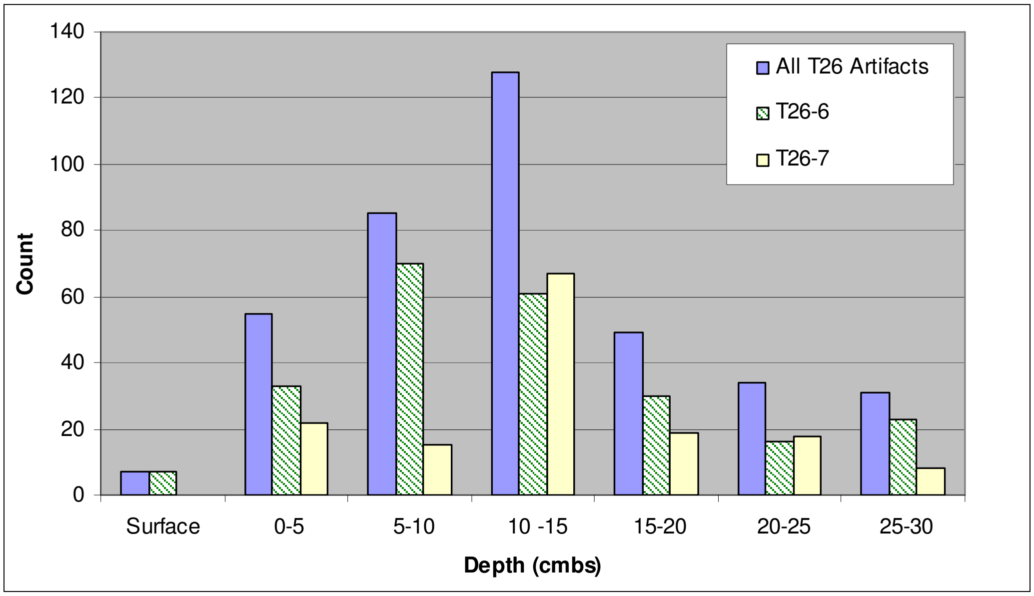
T26-6 and T26-7 are located approximately 13 meters upslope of the pond bottom (Figure 3.7). The units were placed on a slope that trends downward north-northeast at approximately 6º to 7º. T26-6 and T26-7 border each other on their south/north edge respectively. Together, T26-6 and T26-7 yielded a total of 395 pieces of culturally modified lithic material within a depth of 30 cmbs (Figure 3.8). Sixty-one percent (n=241) of the chipped stone in the T26 units was recovered from T26-6, the downslope test excavation unit. T26-7 yielded total of 39% (n=150) of the artifacts collected in the T26 units.

3.7. Location of Excavation Test Units



The trend in artifact frequency in both units is an increase in lithic materials beginning at 5 cmbs, peaking around 15 cmbs, steadily decreasing to 30 cmbs. The maximum depth of buried cultural material is unknown as excavation ceased prior to reaching sterile sediment due to time limitations.

Figure 3.7. Block T26: Artifact Frequency by Depth

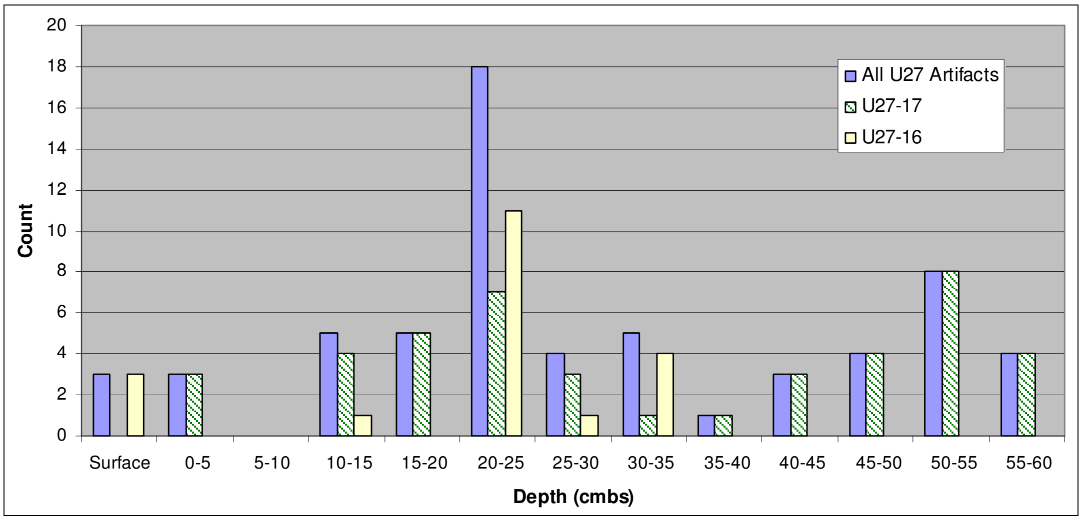


Block U27 is located north and east of T26 along the southern edge of the sag pond. Together the two units U27-16 and U27-17 yielded a total of 64 lithic artifacts. Twice the amount of sediment was removed from U27 (60 cmbs) as compared to T26, however the units contained only 13% of the total number of artifacts recovered during test excavation. U27-16 and U27-17 were initially excavated by quadrant, then, due to the lack of cultural material, at 30 cmbs units were excavated as 1 by 1 m areas.

Almost 70% of artifacts found in U27 were recovered from U27-17, the upslope unit (n=44). Artifact frequency in U27-17 displays a bimodal distribution with peaks at 20 cmbs and 50 cmbs (Figure 3.8). Three artifacts were found on the surface of U27-16 and only one artifact was recovered in the first 15 cm of sediment excavated. U27-16 had an increase in artifact frequency at 20 cmbs. Although there is an increase in lithic material with depth, no more than 15 flakes were found in any given level in U27-16 and

U27-17 combined. The final level excavated in both units contained artifacts. As stated above, the depth of buried cultural deposits was not determined due to time limitations.

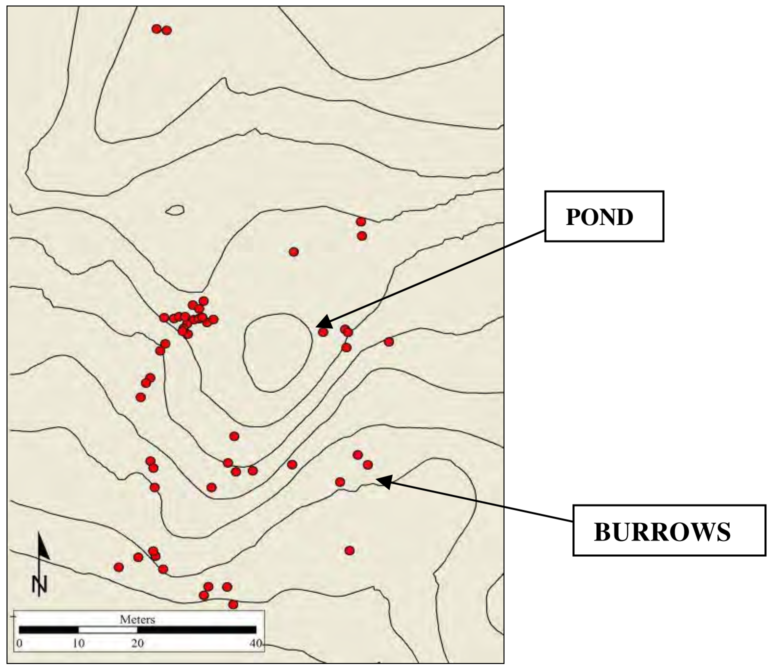
Figure 3.8. U27 Artifact Frequency by Depth



Summary of Pocket Gopher Documentation

Fifty-three areas of pocket gopher activity were documented in the one-hectare sample area (26 mounds, 27 soil casts) (Figure 3.9, Table 3.3). The total volume of displaced material was 309.6 liters. Of the 309.6 liters, 249.1 liters consisted of sediment and 60.5 liters of rock, approximately a 4:1 ratio. The volume of material associated with individual burrows ranged from 0.3 to 28.4 liters, with an average of 5.8 liters per location. Seventeen burrows were active and 34 had no evidence of current occupation. Activity was not determined for the two mounds recorded on the final day of fieldwork, as researchers did not return to the site to monitor for newly ejected sediment. A total of 114 pieces of flaked stone were recovered from gopher disturbed sediment, a density of approximately 4 artifacts/ m^2. Other than lithic debris, no other types of culturally modified or non-cultural material, such as bone, were recovered from burrows.

Figure 3.9. Distribution of Pocket Gopher Burrows in 1-Ha Sample Area



The surface area disturbed by pocket gopher activity was calculated using the length and width of each mound. Since only the length of soil casts was recorded in the field, the average width of gopher tunnels, 15 cm (Gabet at el. 2003) was used to determine the ground surface covered by soil casts. The length and width of eight mounds was not recorded and to adjust for the missing data, the average size of mounds in the study area was substituted (0.5 m^2). Calculations show pocket gophers disturbed 28.2 m^2, or 0.28%, of the hectare (10,000 m^2) study area.

Table 3.3. Summary of Pocket Gopher Data in 1-Hectare Sample Area

Burrow		Sediment (liters)	Rock (liters)	Flakes	Current Occupation			Surface Area
Mound	Soil Core				Active	Inactive	Unknown	
26	27	249.1	60.5	114	17	34	2	28.2 m²

Gopher Activity in the Pond Catchment Area

Thirty-six of the 53 burrows are located within the catchment area (19 mounds, 17 soil casts) (Table 3.4). The volume of material disturbed by pocket gopher activity in the 1-hectare area totaled 147.9 liters, of which 113.2 liters were sediment and 34.7 liters rock. The volume of sediment in individual gopher burrows varies from 0.2 to 14.4 liters. Approximately one-third of the burrows were occupied at the time of documentation. Although the pond catchment area represents only 19% of the sample area, it contains well over half the burrows (68%) and almost half (48%) the sediment and rock disturbed by pocket gophers in the entire study area. Pocket gopher activity covers 15.8 m² (0.8%) of the catchment surface area. Compared to the entire sample area, the pond catchment has a higher density of burrows and greater extent of surface disturbance. This distinction may indicate that the vegetation, sediment, and topographic characteristics of the pond area are more suitable for pocket gopher habitation than the area outside the pond.

Table 3.4. Pocket Gopher Data: Burrows Located in Pond Catchment Area

Burrow		Sediment (liters)	Rock	Flake	Current Occupation			Pond Area (m²)	
Mound	Soil Cast				Active	Inactive	Unknown	Total	Disturbed
19	17	113.2	34.7	49	12	24	0	1880m²	15.8m²

Non-culturally Modified Stone Distribution

The size of rocks pocket gophers are capable of transporting is limited by tunnel diameter. Johnson (1989:372) found gophers will not transport clasts greater than 6 – 7 cm diameter; other research found material greater than 5 cm in diameter was not transported (Bocek 1886:591). In montane environments, rocks measuring 0.6 cm to 2.5 cm in diameter were more abundant in gopher disturbed sediment than the surrounding ground surface (Hansen and Morris 1968:391). At 48PA2874 gopher disturbed sediment contained clasts measuring over 5 cm, including one stone with a length of 25 cm (Table 3.5). Analysis of rock samples from mound sediment at the site reveals 87% of rocks were less than 1.13 cm in length. Rocks with lengths between 4.5 and 25 cm comprised only 2% of the sample. The size distribution of clasts found in soil casts was similar to that of mounds, although no rocks larger than 6.4 cm were found in soil casts (Table 3.4). It is possible larger clasts are not being transported, but rather dislodged by pocket gopher activity.

Chipped Stone

Mound and soil cast sediment was screened with a 4.76 mm (0.187 in) wire mesh screen to determine the presence of archaeological material. All artifacts found during screening were collected for further analysis. A total of 114 pieces of culturally modified lithic material were recovered from 29 burrows. Burrows contained a wide range of artifact types, including flakes (84%), worked flakes (4%), angular debris (6%), bifaces (2%), a core (1%), an awl (1%), an end scraper (1%), and a side scraper (1%). The number of flakes found within pocket gopher sediment was not correlated with the volume of disturbed material per burrow. The greatest number of artifacts (n=16) recovered from a single burrow was found in only 1.7 liters of disturbed sediment. Artifacts tended to be located on the gentle slope south of the pond and the level saddle to the west. No artifacts were recovered from pocket gopher sediment on the steeper eastern slope.

Table 3.5 Rock Size Distribution in Mounds and Soil Casts

	Clasts in Mounds		**Clasts in Soil Casts**	
Length	**Count**	**% of Total**	**Count**	**% of Total**
4 mm	298	5.6%	95	2.4%
5.7 mm	1832	35%	1035	25.8%
8 mm	1659	31.6%	1255	31.3%
11.3 mm	772	14.7%	797	19.8%
16 mm	339	6.4%	417	10.4%
22.6 mm	162	3.1%	221	5.5%
32 mm	40	0.8%	103	2.5%
45 mm	64	1.2%	89	2.2%
64 mm	39	0.74%	3	0.1%
>64 mm	25	0.5%	-	-
9 cm	13	0.24%	-	-
12.8 cm	5	0.1%	-	-
25 cm	1	0.02%	-	-
Total	**5249**	**100%**	**4019**	**100%**

The following chapter analyzes data outlined above to gain a better understanding of the geomorphic impacts of pocket gopher activity and influence on artifact distribution at 48PA2874. As mentioned previously, additional information the site surface assemblage can be found in Appendix A. Test excavation data and statistical analysis are located in Appendix B.

CHAPTER 4

RESULTS AND INTERPRETATIONS

Test Excavation Analysis

To identify trends in the subsurface distribution of cultural material, the physical attributes of artifacts were compared by level, unit, and block. Analysis also included comparing subsurface material with site surface artifacts and those recovered from pocket gopher mounds. Shape indices, including elongation, flatness, blockiness/sphericity, and weight, and the maximum length of lithic material were compared between artifact groups using Levene's test for variance and *t*-tests for means.

Artifact data from T26-6 and T26-7 were combined and artifact characteristics analyzed by depth (Table 4.1). Lithic material found on the surface of the units had the greatest average length (15.5 mm) and the greatest variance from the mean ($\sigma = 10.04$), while artifacts 0 – 5 cmbs had the lowest mean length (8.6 mm) and the lowest standard deviation ($\sigma = 4.02$). With depth the average length of artifacts steadily increases until 25 – 30 cmbs where there is a slight decrease. The variation in artifact length has a pronounced increase between 10 – 15 cmbs ($\sigma = 7.73$), then a decrease until 25 – 30 cmbs where standard deviation again increases ($\sigma = 6.71$).

Table 4.1. Mean Values of Artifact Characteristics by Depth: All Levels of T26

	Count	Length (mm)	Elongation	Flatness	Blockiness	Weight Ratio
Surface	12	15.5	0.70	0.26	0.04	9.37
0-5	55	8.65	0.744	0.185	0.0347	5.39
5-10	85	8.74	0.692	0.196	0.0319	5.23
10-15	128	10.17	0.737	0.234	0.0411	6.61
15-20	49	10.83	0.714	0.231	0.0361	6.63
20-25	34	11.1	0.70	0.21	0.0361	6.70
25-30	31	10.24	0.734	0.220	0.0403	6.61
Average	**n = 394**	**10**	**0.72**	**0.22**	**0.04**	**6.24**

T-tests were used to compare the physical characteristics of artifacts in T26 by level; meaning artifacts found 0 -5 cmbs were compared with those from 5 -10 cmbs, 10 – 15 cmbs and so on. Results showed a statistically significant difference in the vertical distribution of artifacts at the alpha 0.05 level between many of the attributes examined. A brief summary of the results is provided below; tabular data of the statistical analysis are located in Appendix B.

Artifacts located between 0 – 5 cmbs and 5 – 10 cmbs had uniform physical properties; there was no statistically significant differences in any of the attributes examined. Artifacts with depth become significantly longer, less flat, and heavier at the alpha 0.05 level. In addition, artifacts from 5 – 10 cmbs were more elongated and more angular than those from 10 – 15 cmbs. There were no significant differences between artifacts from any level and those from 25 – 30 cmbs.

A comparison of T26-6 and T26-7 artifacts by level shows little variation in the characteristics examined. T26-6 contained more artifacts per level than T26-7, with the exception of 10 – 15 cmbs and 20 – 25 cmbs. Only two artifact characteristics had statistically significant differences at the alpha 0.05 level. Artifacts recovered from 0 – 5 cmbs from T26-7 were significantly more angular than those from T26-6. At 15 – 20 cmbs T26-7 artifacts were more elongated.

In T26-7 there is a change in artifact frequency that corresponds to a change in sediment characteristics. The A horizon in the western portion of T26-7 consists of colluvial and alluvial deposits of light brownish grey (10YR6/2) sandy loam that overlays a horizon of unsorted, angular, decomposing cobbles in a clay-rich, tan-mottled matrix. The cobble layer, formed by slump-earthflow events, emerges around 15 cmbs in the most upslope quadrant of T26-7 (SW corner of the SW quadrant) and extends with depth to the northeast, following the curve of the landform (Figure 4.1). As the cobble layer was revealed, artifact frequency decreased substantially. A similar relationship between artifact frequency and sediment change can not be evaluated in T26-6 because the large cobbles and tan sediment were only beginning to be uncovered in the southwestern quadrant when excavation ceased.

The low number of artifacts recovered from U27 makes conducting statistical analysis on artifact characteristics between levels difficult. The small sample size has the potential to introduce substantial bias and skew any statistical analysis of artifact attributes. The average values of maximum length and the shape indices are provided in Table 4.2. No correlations between depth and artifact length or shape indices could be identified in U27. Both units had a wide size range per level, with artifact lengths measuring between 4 mm to 39 mm. Statistical analysis of artifact characteristics by depth is not provided due to the small number of artifacts per level.

Figure 4.1. T26-6 and T26-7:
Exposure of Slump-Earthflow Deposits

Photography by L.C. Todd

Table 4.2. U27: Mean Values of Shape Indices

CMBS	Count	Length (mm)	Elongation	Flatness	Blockiness	Weight
Surface	1	5.3	0.566	0.233	0.4213	3
0-5	3	8.7	0.829	0.215	0.035	5.8
5-10	-	-	-	-	-	-
10-15	4	11.25	0.744	0.266	0.521	7.83
15-20	5	16.8	0.773	0.307	0.061	10.94
20-25	7	5.08	0.492	0.274	0.329	2.77
25-30	4	14.7	0.813	0.186	0.042	9.14
30-35	1*	-	-	-	-	-
35-40	1	56.8	0.871	0.337	0.635	41
40-45	3	9.8	0.694	0.246	0.470	6.10
45-50	4	11.6	0.580	0.133	0.352	6.37
50-55	8	19.51	0.621	0.289	0.452	11.18
55-60	4	18.4	0.746	0.189	0.467	12.12

*Missing Data

U27 had no identifiable shift in artifact frequency that correlated with a change in sediment characteristics. Other than a slight increase in fine particulate matter with depth, sediment color (10YR 4/2, dark grayish brown) and structure (massive) was uniform throughout both units. The tan mottled sediment with cobbles found in T26 was not reached in U27. As discussed below, this suggests greater sediment accumulation has occurred in the pond units since the slump-earthflow event.

Comparing Subsurface and Surface Artifact Characteristics

There was a statistically significant difference in physical characteristics of subsurface and surface artifacts. All artifact data from the two U27 units were grouped prior to analysis due to the small number of specimens recovered during testing. Artifacts from T26 were compared with surface artifacts by depth. *T*-tests of surface and

U27 artifacts show subsurface artifacts are statistically shorter, more elongated, more angular, and lighter than surface artifacts.

Every level of T26 showed statistically significant differences in maximum length and weight, with subsurface artifacts being smaller and lighter than surface material (Appendix B). Subsurface artifacts were statistically more flat at all depths except 15 – 20 cmbs and more angular with the exception of 10 – 15 cmbs. Elongation of surface and subsurface material was only significantly different between 5 – 10 cmbs, with subsurface material being more elongated.

Test Excavation: Inferences on Formation Processes

Test excavation showed buried cultural material is present at the site at least as deep as 60 cmbs. Soil profiles from the test excavation units provided a glimpse of formation processes occurring at a broad spatial scale. Specifically, profiles were examined for evidence of the slump-earthflow event on which the site sits. Sediment characteristics are consistent with what would be expected: Upslope deposits consist of a thin A-horizon with uniform texture and color then an abrupt transition to an unsorted mass of brown-grey mottle sediment, gravels, and cobbles. The A-horizon gets thicker as the slope becomes more level toward the pond. The greatest sediment accumulation occurs within the pond due to the deposition of particulate matter eroding from upslope. As mentioned previously, the slump-earthflow event, indicated by the unsorted cobble horizon, was not encountered in the pond during test excavation. An auger probe was placed in U27-17 to determine the depth of the slump-earthflow deposit within the pond. The auger probe revealed a transition to clay-rich, tan, grey, and brown mottled sediment at approximately one meter below the ground surface, however no cobbles were encountered. The auger probe continued only 15 cm below the initial change in sediment characteristics and may not have gone deep enough to reach the cobble layer.

The discrepancy in size and shape between buried and surface material may indicate subsurface artifacts are not in their primary context. In general, buried artifacts were smaller, flatter, more angular, and lighter than surface artifacts. Chipped stone from T26 has less variation from the mean than surface artifacts in almost all artifact characteristics at all depths. The comparison of artifacts from U27 and surface artifacts showed statistically significant differences in all categories with the exception of flatness.

If smaller artifacts are being transported across the ground surface by processes such as overland flow, then it might be reasoned that the frequency of artifacts would increase as the landform begins to level out further downslope. Both T26-6 and T26-7 have the greatest number of artifacts in the most downslope quadrants. U27-16, the most downslope of all four test units, and the unit located on the most level ground, contains the smallest number of artifacts. This may be due to landform characteristics. Deposition will occur where either the slope flattens enough to impede transport or obstructions occur (Hilton 2003). The slope above U27-16 may be gentle enough for artifacts to have been deposited prior to reaching the unit.

Determining if artifact distribution in the test excavation units is a result of human behavior or natural processes with this level of analysis is not possible. The tendency of subsurface lithic materials to be smaller and lighter than those on the site surface suggests the possibility that artifacts are being relocated by post depositional processes. As discussed in Chapter 2, there are multiple geomorphic processes in high elevation environments capable of transporting artifacts. Bioturbation from pocket gophers is one of these processes. The following section addresses the impact of their activity on vertical and horizontal artifact distribution at 48PA2874.

Pocket Gopher Borrow Analysis

The objectives of pocket gopher documentation are to identify topographic controls on burrow placement, examine erosion of pocket gopher disturbed sediment, and begin initial evaluation of pocket gopher influence on horizontal and vertical artifact distribution. To identify spatial patterns in habitat selection, the locations of pocket gopher activity were examined in conjunction with high resolution topographic data. Spatial analysis was conducted at two geographic scales, one covering the entire 1 hectare sample area for a generalized view of burrow location, and the other focusing on the pond catchment area to examine localized preferences.

Redistribution of sediment disturbed by pocket gophers is examined by comparing the physical properties of actively occupied burrows with deflated, abandoned burrows. Abandoned burrows have been exposed to erosion for a longer period of time than the active burrows and should exhibit different sediment properties. For instance, older mounds and soil casts are expected to contain a lower proportion of silt and clay than freshly churned sediment due to the vulnerability of small particles to erosion. To identify patterns, similarities, or differences in the distribution of archaeological material, the physical characteristics of artifacts recovered from pocket gopher mounds are compared with those from test excavation units and the site surface. The following section reports pocket gopher data and analyzes the results.

Spatial Distribution of Burrows: Aspect, Elevation, and Slope

Almost 90% of pocket gopher mounds and tunnels in the study area are on north facing slopes. No evidence of pocket gopher activity was located on south, southeast, or southwest facing slopes. Only 2% of burrows were found on west facing slopes. Slopes with western and southern aspects have the greatest exposure to sunlight, resulting in higher soil temperatures, lower soil moisture, and sparse vegetation, all of which deter gopher occupation. Northern slopes retain snow pack longer, providing insulation from cold winter temperatures and protection from predators. Approximately half (48%) of winter pocket gopher activity, indicated by soil casts, occurred on north facing slopes. Less than one-third (27%) of mounds, which are created in snow-free conditions, are located on north-facing slopes (Table 4.3).

Table 4.3. Distribution of Gopher Burrows in Sample Area: Aspect

Aspect	All Burrows	Soil Casts	Mounds
N	38%	48%	27%
NE	34%	30%	38%
NW	17%	7%	27%
E	9%	11%	8%
W	2%	4%	0%
SE	-	-	-
SW	-	-	-
S	-	-	-
Total	**100%**	**100%**	**100%**

Pocket gophers occupied elevations between 3090 m to 3104 m (Table 4.4). Although not a large span, even small differences in elevation can impact micro-environmental conditions. Gopher activity was least frequent at the extreme ends of the elevation spectrum. Of all burrows, almost half (49%) were located between elevations of 3098 m and 3100 m. A slightly higher percentage of tunnels than mounds were located within the lowest elevation range. This may be due to the seasonal influx of melt water into depressed areas, making conditions habitable only in the winter (Zaitlin, et al. 2007). Evidence of gopher activity within the sag pond was minimal, consisting of only one small surface opening with little associated loose sediment. Gophers may periodically explore the pond, although the high soil moisture inhibits long-term occupation.

Table 4.4. Distribution of Gopher Burrows in Sample Area: Elevation

	All Burrows		Mounds		Tunnels	
Elevation (m)	**Count**	**Percent**	**Count**	**Percent**	**Count**	**Percent**
3098 – 3100	26	49%	11	42%	15	56%
3100 – 3102	11	21%	8	31%	3	11%
3102 – 3104	16	30%	7	27%	9	33%
Total	**53**	**100%**	**26**	**100%**	**27**	**100%**

Slope in the sample area ranged from 2º to 15º. Despite this wide range, pocket gopher activity was evenly distributed across gradients and similar for mounds and tunnels (Table 4.5). Slope did not appear to be a significant factor in burrow placement at 48PA2874, a finding consistent with (Reichman and Seabloom 2002; Seabloom, et al. 2000) who found no correlation between tunnel characteristics and hill slope angle.

Table 4.5. Distribution of Gopher Burrows in Sample Area: Slope

	All Burrows		Mounds		Tunnels	
Range	**Count**	**%**	**Count**	**%**	**Count**	**%**
2º to 4º	13	24%	4	15%	6	22%
5º to 7º	12	23%	6	24%	9	33%
8º to 10º	11	21%	4	15%	6	22%
11º to 13º	11	21%	8	31%	4	15%
13º-15º	6	11%	4	15%	2	8%
Total	**53**	**100%**	**26**	**100%**	**27**	**100%**

The analysis of aspect, elevation, and slope and pocket gopher activity in the catchment basin was consistent with the results from the larger sample area.

Approximately 75% of the burrows in the pond drainage area are located on north facing slopes (Table 4.6c). No burrows are present on south, southeast, or southwest facing slopes. Over twice as many soil casts are located on slopes facing north than are mounds (47% of soil casts, 21% of mounds). No mounds are present on slopes with a western aspect. Elevation in the pond catchment area ranges from 3094 to 3110 m (Table 4.6a). Like the 1-hectare sample area, half the burrows are located in the mid-range, between elevations of 3098 to 3100 m. Gradient did not appear to impact burrow placement as pocket gopher activity was evenly distributed across the range of slope (Table 4.6b).

Table 4.6. Elevation, Slope, and Aspect of Burrows in Pond Catchment Area

Table 4.6a. Elevation		
Elevation (m)	**Count**	**% of Total**
3098 – 3100	18	50%
3100 – 3102	10	28%
3102 – 3104	8	22%
Total	**36**	**100%**

Table 4.6b. Slope		
Slope	**Count**	**% of Total**
2º to 4º	8	22%
5º to 7º	8	22%
8º to 10º	7	20%
11º to 13º	8	22%
13º to 15º	5	14%
Total	**36**	**100%**

Table 4.6c. Aspect			
Aspect	**All Burrows**	**Soil Casts**	**Mounds**
N	33%	47%	21%
NE	39%	29%	47%
E	8%	18%	0%
NW	17%	0%	32%
W	3%	6%	0%
SE	-	-	-
S	-	-	-
SW	-	-	-
Total	**100%**	**100%**	**100%**

Pocket Gopher and Site Surface Artifacts

The largest artifact found in gopher disturbed sediment measures 48.4 mm, conforming to the size of objects expected to be transported (Bocek 1986:591). As shown in Table 4.7, the maximum length of a surface artifact (96.9 mm) is twice as long as the largest artifact recovered from a pocket gopher burrow. The minimum length of a gopher burrow artifact (4.8 mm) is three-times larger than the smallest surface artifact (1.4 mm). Despite these apparent differences, analysis showed neither the variance nor mean length of artifacts in gopher mounds and the site surface differed significantly at the alpha .05 level (p=0.288).

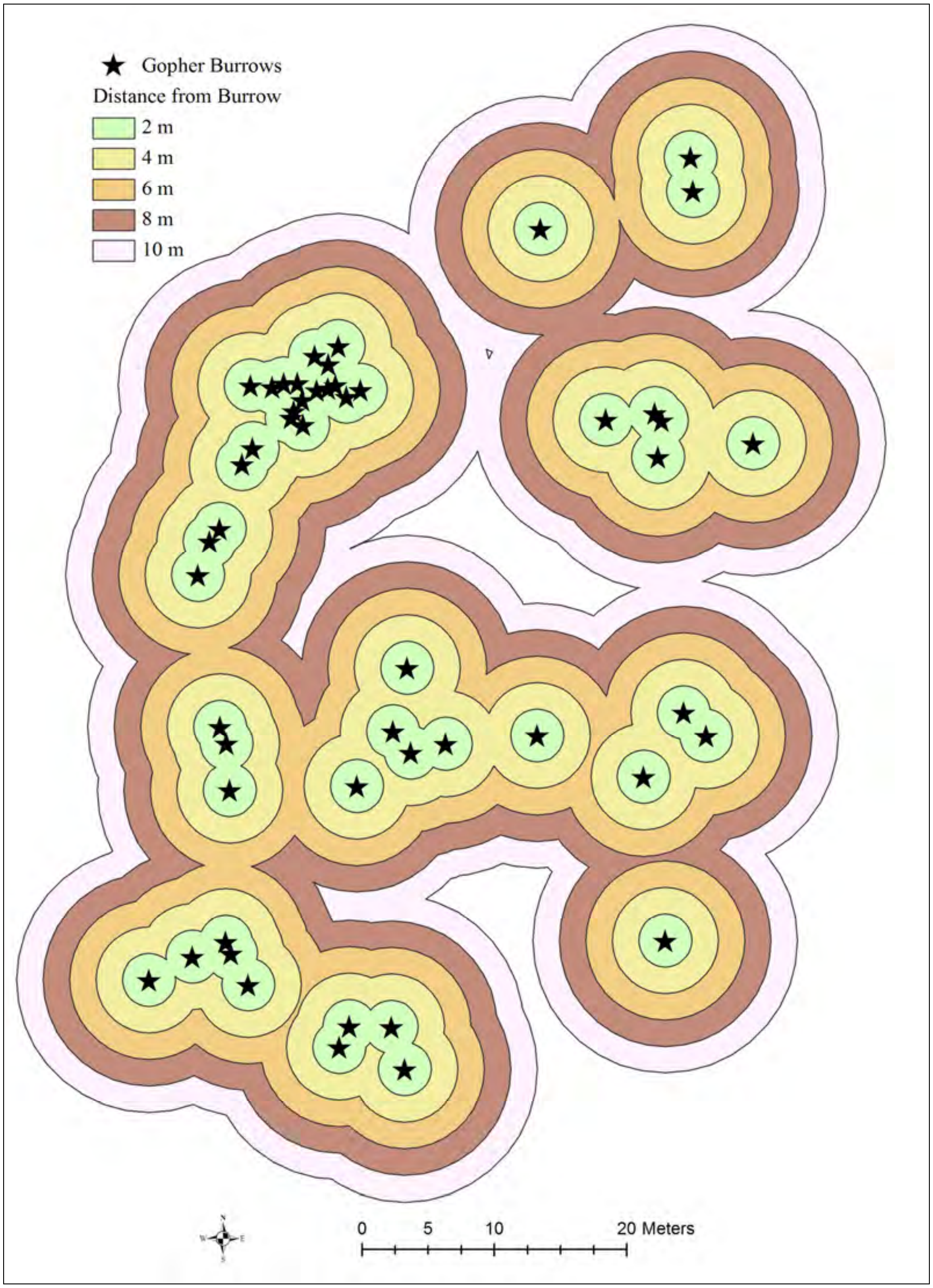
A difference in artifact length was not evident at site-scale, however localized size sorting of artifacts may be occurring. The influence of gopher activity on artifact distribution in a spatially limited area was examined using GIS software ArcGIS 9.1. The program was used to delineate 2 m, 4 m, 6 m, 8 m, and 10 m 'buffer' zones that extended from the center of each gopher burrow (Figure 4.2).

Table 4.7. Artifact Length: Gopher Burrows, Site Surface, and Buffered Analysis Zones

Location	# Artifacts	Mean (mm)	Maximum (mm)	Minimum (mm)	Standard Deviation
Gopher	114	14.9	48.8	4.8	8.5
Site	2465	15.6	96.9	2.4	9.63
0 – 2 m	74	17.16	72	6	11.99
2 – 4 m	131	16.41	56	5	8.54
4 – 6 m	225	15.25	47	5	7.49
6 – 8 m	210	16.98	74	5	9.85
8 - 10m	207	15.41	97	6	10.14
0 – 4 m	205	16.68	72	5	9.91
6 - 10 m	435	16.09	74	5	8.74

The physical characteristics of artifacts located within each buffer zone were compared with artifacts found in burrows to determine if cultural material located closer to gopher-disturbed areas were being sorted by shape. Artifacts located in preceding buffer areas were not included in the analysis of subsequent buffer; meaning artifacts within the two-meter buffer were not included in the analysis of the four-meter buffer area. To account for potential error introduced by variation in GPS accuracy, two additional buffer-area sizes, 0 m - 4 m (4 m span) and 6 - 10 m (4 m span) were examined. Results were consistent with 2 meter interval buffer zones.

Figure 4.2. Pocket Gopher Burrows and Localized Analysis Zones



Analysis does not reveal striking differences between artifact characteristics based on distance from pocket gopher burrows. The greatest variation in length occurs between gopher burrow artifacts and the two-meter buffer zone (Table 4.7). Artifacts in gopher disturbed sediment have the smallest average length (14.8 mm) of all the buffer zones. The two-meter buffer zone contains artifacts with the greatest average length (17.16 mm). There is a difference in the minimum length of artifacts within 10 m of gopher disturbed sediment and the site assemblage as a whole. No artifacts within 10 m of gopher activity are less than 5 mm in size; while the minimum length of surface assemblage is 2.4 mm. *T*-tests showed no significant difference in the mean length of gopher burrow artifacts and surface artifacts at all spatial intervals at the alpha 0.05 level. There may be a weak trend where artifacts in gopher burrows are smaller and have less variation than those within two meters; however the differences are not statistically significant.

Shape Indices: Pocket Gopher Artifacts and the Surface Assemblage

The mean elongation value for artifacts in gopher burrows is 0.74, indicating a tendency for equality in length and width. The mean elongation values of site surface artifacts at all distance intervals were similar to those in gopher burrows (from 0.72 to 0.74). The flatness value for artifacts in pocket gopher sediment and site artifacts at all distances was also consistent (from 0.25 to 0.28). Neither the variance nor mean elongation and flatness values were statistically different at the alpha .05 level (Table 4.8 and Appendix B).

Table 4.8. Gopher Burrows and Surface Artifacts: *t*-test of Shape Indices

	Elongation	**Flatness**	**Blockiness**	**Weight**
Location	**Sig. (2-tailed)**	**Sig. (2-tailed)**	**Sig. (2-tailed)**	**Sig. (2-tailed)**
Site Surface	0.229	0.632	0.959	.094
0 – 2 m	0.135	0.194	0.222	0.191
2 – 4 m	0.669	0.334	0.227	0.089
4 – 6 m	0.178	0.576	0.576	0.659
6 – 8 m	0.139	0.588	0.920	0.053
8 – 10 m	0.111	0.591	0.791	0.787
0 – 4 m	0.506	0.231	0.283	0.238
6 - 10 m	0.118	0.551	0.904	0.241

The blockiness/sphericity values for gopher burrows, site surface artifacts, and each buffer zone were all centrally located along the sphericity scale with values at approximately 0.5. Analysis indicated neither variance nor mean sphericity of gopher burrow artifacts and site surface artifacts was statistically significant at the alpha 0.05 level (Table 4.8 and Appendix B).Weight values of gopher disturbed artifacts and those on the site surface at all distance intervals showed little deviation, ranging from 9.7 to 10.5. Neither variance nor mean weight was statistically significant at the alpha 0.05 level (Table 4.8 and Appendix B).

Pocket Gopher and Subsurface Artifacts

The same characteristics used to compare artifacts on the site surface and those in gopher sediment (length, elongation, flatness, blockiness, and weight) were applied to artifacts recovered from test excavation units. The larger quantity of lithic debris recovered from T27-16 and T26-17 provided a more appropriate sample size to use in level-by-level analysis. The U27 units contained too few specimens per level to provide a reasonable comparison by depth. Therefore, artifact data from all levels of both U26 units were combined to look for generalized similarities or difference with gopher burrow artifacts.

Artifacts recovered from excavation units U27-16 and U27-17 were on average smaller, more elongated, flatter, more angular, and lighter than artifacts found within pocket gopher disturbed sediment (Appendix B). U27 had less variation in elongation, flatness, and blockiness, and greater variation in length and weight. Two of the characteristics compared had statistically significant differences in means at the alpha 0.5 level. Artifacts in the U27 units were significantly more elongated and angular than gopher artifacts.

Data from T27-6 and T27-7 were combined by 5 cm levels and compared with pocket gopher artifacts level-by-level. The physical characteristics of gopher mound artifacts and those recovered from T26 were markedly dissimilar. *T* - tests revealed lithic debris from pocket gopher mounds was statistically longer and heavier than artifacts in T26 at all depths (Table 4.9). Pocket gopher artifacts were significantly more rounded in every level except 10 – 15 and 25 – 30 cmbs. Excavation artifacts were statistically flatter than gopher artifacts from 1 – 10 cmbs. The difference in mean elongation was only statistically significant between 5 – 10 cmbs, with excavation artifacts being more elongated.

Table 4.9. Gopher Burrows and Subsurface Artifacts: *t*-test of Shape Indices

***t*-test** Sig. (2-tailed)						
T26	**0 – 5 cmbs**	**5 – 10 cmbs**	**10 – 15 cmbs**	**15 – 20 cmbs**	**20 – 25 cmbs**	**25 - 30 cmbs**
Length	0.000*	0.000*	0.000*	0.003*	0.014*	0.006*
Elongation	0.863	0.016*	0.551	0.207	0.126	0.673
Flatness	0.000*	0.001*	0.281	0.355	0.104	0.258
Blockiness	0.005*	0.000*	0.273	0.023*	0.005*	0.476
Weight	0.000*	0.000*	0.000*	0.000*	0.000*	0.007*

**Significant at the alpha 0.05 level*

Sediment Analysis

As noted previously, if erosion is redistributing material disturbed by pocket gophers, fresh mound sediment will have different characteristics than winter soil casts that have been exposed to erosive processes for a longer period of time. It is proposed that sediment from active mounds will have a greater proportion of fine particulate matter than winter soil casts or abandoned mounds. Because sediment samples were collected in mid-summer, it was presumed that soil casts had been exposed between 30 and 60 days, depending on topographic position and snow depth.

Within the 1-ha study area, particle size analysis was conducted on 25 samples of mound and soil core sediment. Fourteen of the samples were from burrows located in the pond catchment area. The result of particle size analysis from all 25 pocket gopher burrows is discussed below, followed by a separate examination of samples from the pond catchment area.

Particle Size in Active vs. Inactive Burrows

As shown in Figure 4.3, the average amount of sand and clay is greater in active burrows. Silt is roughly equivalent regardless of occupation status. Levene's test for variance at the alpha 0.05 level indicates no statistical difference in the percent of sand, silt, and clay. *T*-tests showed only the proportion of clay in occupied and abandoned burrows was significantly different at the alpha 0.05 level ($p = 0.02$). It can be noted that sand only misses significance at the alpha 0.05 level ($p = 0.058$) (Table 4.10).

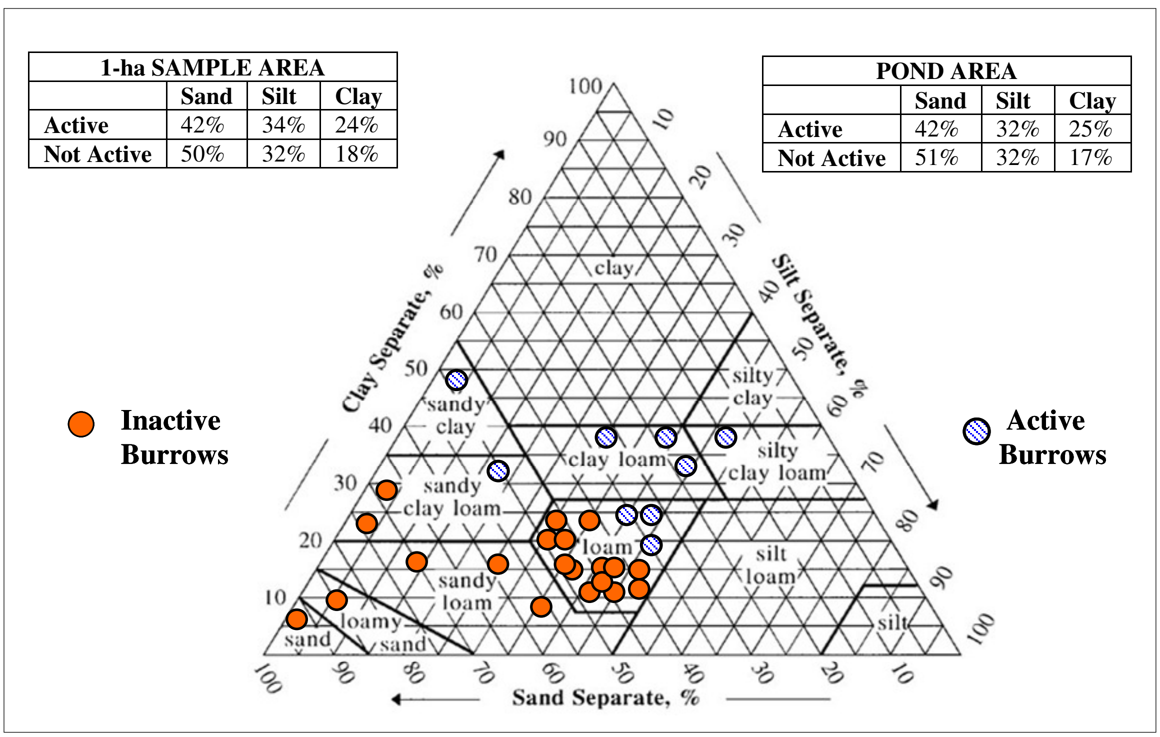
The results of particle size analysis from burrows located in the pond catchment area were similar to the rest of the study area (Figure 4.3). Sand and silt did not have statistically significant differences in variance or mean. A *t*-test for clay in active and inactive burrows was statistically significant ($p = 0.03$) (Table 4.10).

Table 4.10. *T*-test of Particle Size:
Active vs. Inactive Pocket Gopher Burrows

1-ha Study Area					
Particle Size	**F**	**Sig.**	**T**	**df**	**Sig. (2-tailed)**
Sand	3.379	.079	-1.993	23	.0581
Silt	.052	.822	0.8047	23	.4292
Clay	2.62	.117	2.445	23	.0225*
Pond Catchment Area					
Sand	.919	.357	-1.611	12	.133
Silt	.012	.913	.440	12	.668
Clay	1.251	.285	2.458	12	0.03*

*Significant at the alpha .05 level

Figure 4.3. Particle Size Distribution:
Active and Inactive Burrows in 1-Ha Sample Area



There are problems with drawing conclusions on erosion from the particle size data. A total of 25 pocket gopher burrows had texture analysis completed; only 14 samples were located in the pond catchment area. This represents just under half the locations of pocket gopher activity documented. When choosing samples for particle size analysis, effort was made to select a representative type of burrows (mounds, soil casts; active, inactive), sizes, and locations, but is possible the samples did not accurately represent gopher activity at the site.

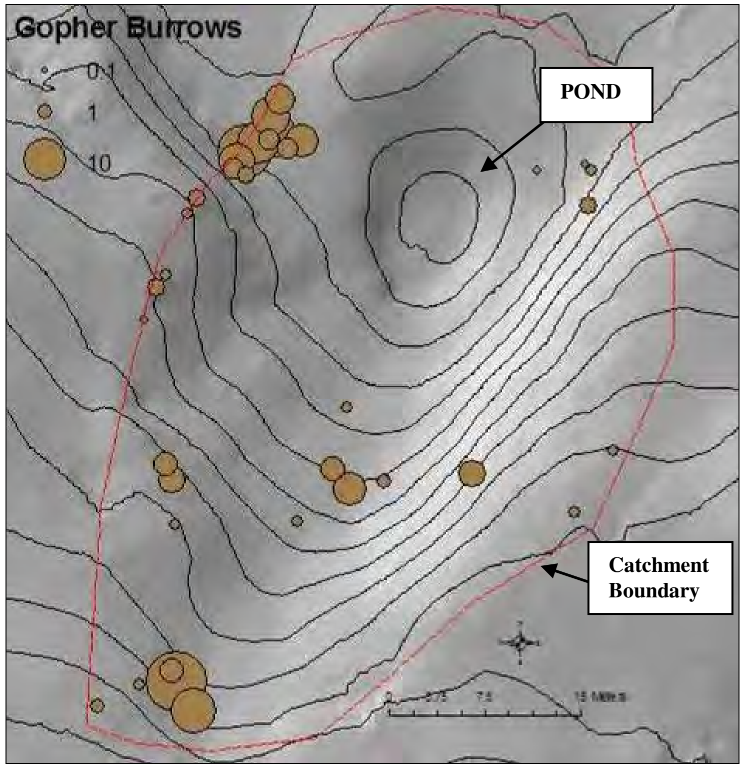
Another potentially significant issue involves the amount of time soil casts and unoccupied mounds have been abandoned. The actual length of exposure is not known. Based on the approximated interval between the date of snow melt and the start of field work, it is estimated that the ground surface had been exposed around 30 days. However snow cover varies considerably across the landscape, resulting in highly localized geomorphic regimes. Some areas have likely remained snow-free all winter, exposing pocket gopher disturbed sediment to the elements year round. In addition to not knowing how long pocket gopher mounds and soil casts have been exposed, the amount of time needed to yield measurable differences in sediment characteristics has yet to be determined. It is possible that more than 30 days is required to significantly erode sediment. Before the extent of erosion resulting from pocket gopher activity is inferred, it is recommended year-long monitoring, mapping, and sampling of disturbed sediment is conducted to truly understand the amount of erosion caused by pocket gophers.

Topographic Influences on Erosion

Topographic characteristics influence the intensity and type of erosion that occur. The steeper the gradient, the lower the energy input needed to initiate particle movement (Ritter et al. 2002: 80). Sediment in gopher burrows was examined by location to determine if erosion was independent of landscape position. Burrows located on steeper, exposed slopes are expected to have a higher proportion of sand than burrows located on more level, protected slopes (Figure 4.4). In addition to burrow sediment, nine samples of undisturbed sediment were collected along a toposequence that began at the highest point on the east ridge and extended to the pond bottom. The samples from the toposequence were analyzed using the hydrometer method, the same technique used with pocket gopher sediment.

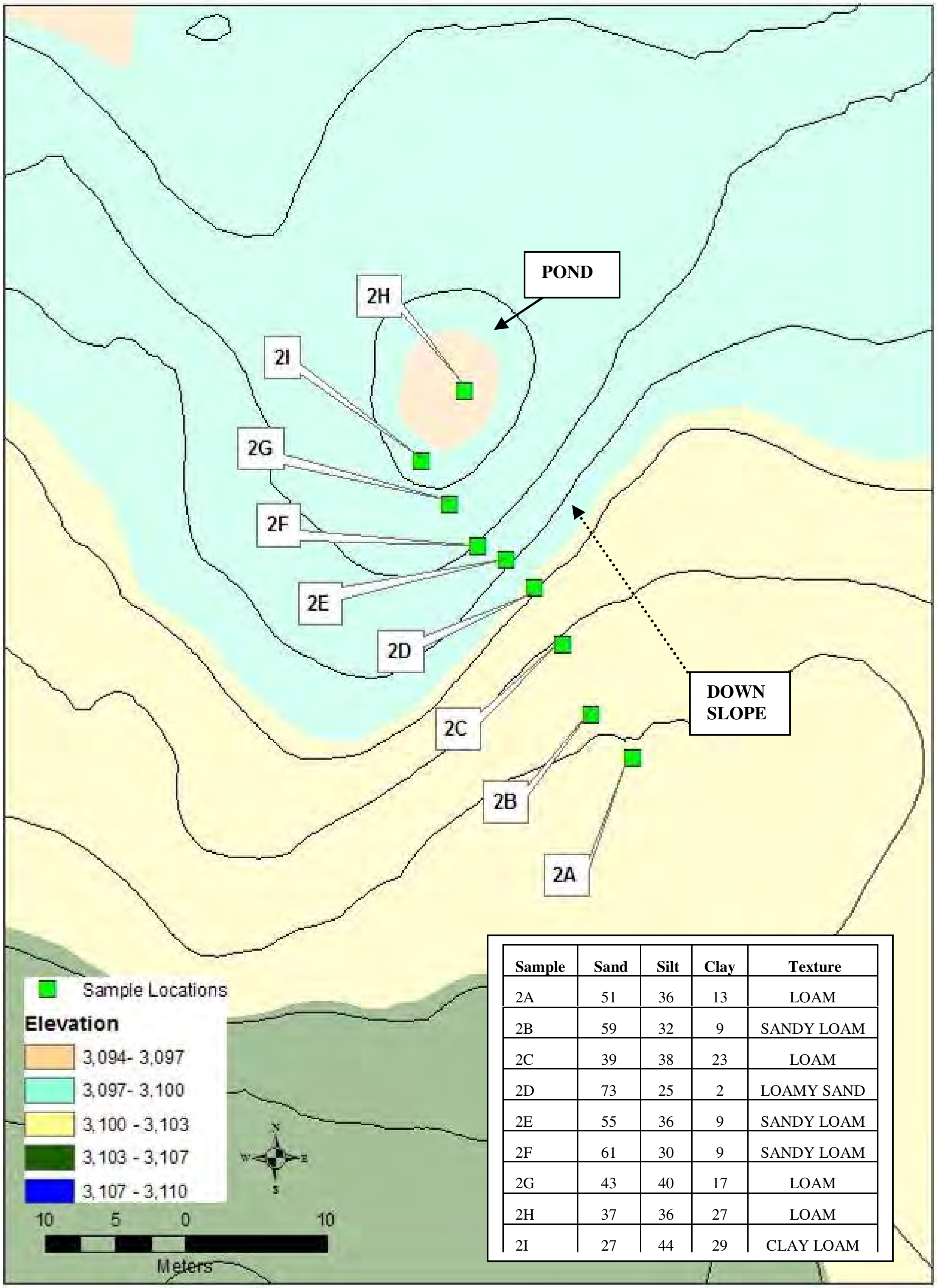
As expected, the proportion of sand in burrows located along the ridge is greater than the proportion of sand in burrows located on the gentle southern and western slopes. Conversely, the percentage of silt and clay in burrows located south and west of the pond is greater than those on the ridge. There is also a notable difference in sediment volume by location. The average volume of sediment in burrows located on the steeper eastern slope is 1.16 liters, while the average for all gopher burrows is 5.8 liters. Burrows located on the south and west sides of the pond have more sediment per burrow than those located on the east, illustrating the inverse relationship between slope and sediment volume. The result of particle size analysis from the toposequence also conforms to expectations. The portion of sand is highest along the steepest slopes and the easier-to-erode silt and clay are the greatest in the areas with gentle gradients (Figure 4.5).

Figure 4.4. Proportional Volume of Sediment per Gopher Burrow in Pond Catchment: Size of Circle Indicates the Amount of Sediment in Relation to Other Burrows



The degree of slope and exposure to wind and water are the primary factors influencing erosion at the site. Gradient on the east side of the pond is more than two-times that on the southern and western slopes, facilitating the removal of smaller particles like silt and clay. The higher ridge to the east may also help protect the areas to the south and west from wind deflation. The variation in sediment volume and particle size in burrows based on landform position indicates topography plays an important role in erosion of pocket gopher disturbed sediment.

Figure 4.5. Sediment Samples from Pond Toposequence



Sample	Sand	Silt	Clay	Texture
2A	51	36	13	LOAM
2B	59	32	9	SANDY LOAM
2C	39	38	23	LOAM
2D	73	25	2	LOAMY SAND
2E	55	36	9	SANDY LOAM
2F	61	30	9	SANDY LOAM
2G	43	40	17	LOAM
2H	37	36	27	LOAM
2I	27	44	29	CLAY LOAM

D90 Erosion Model Results

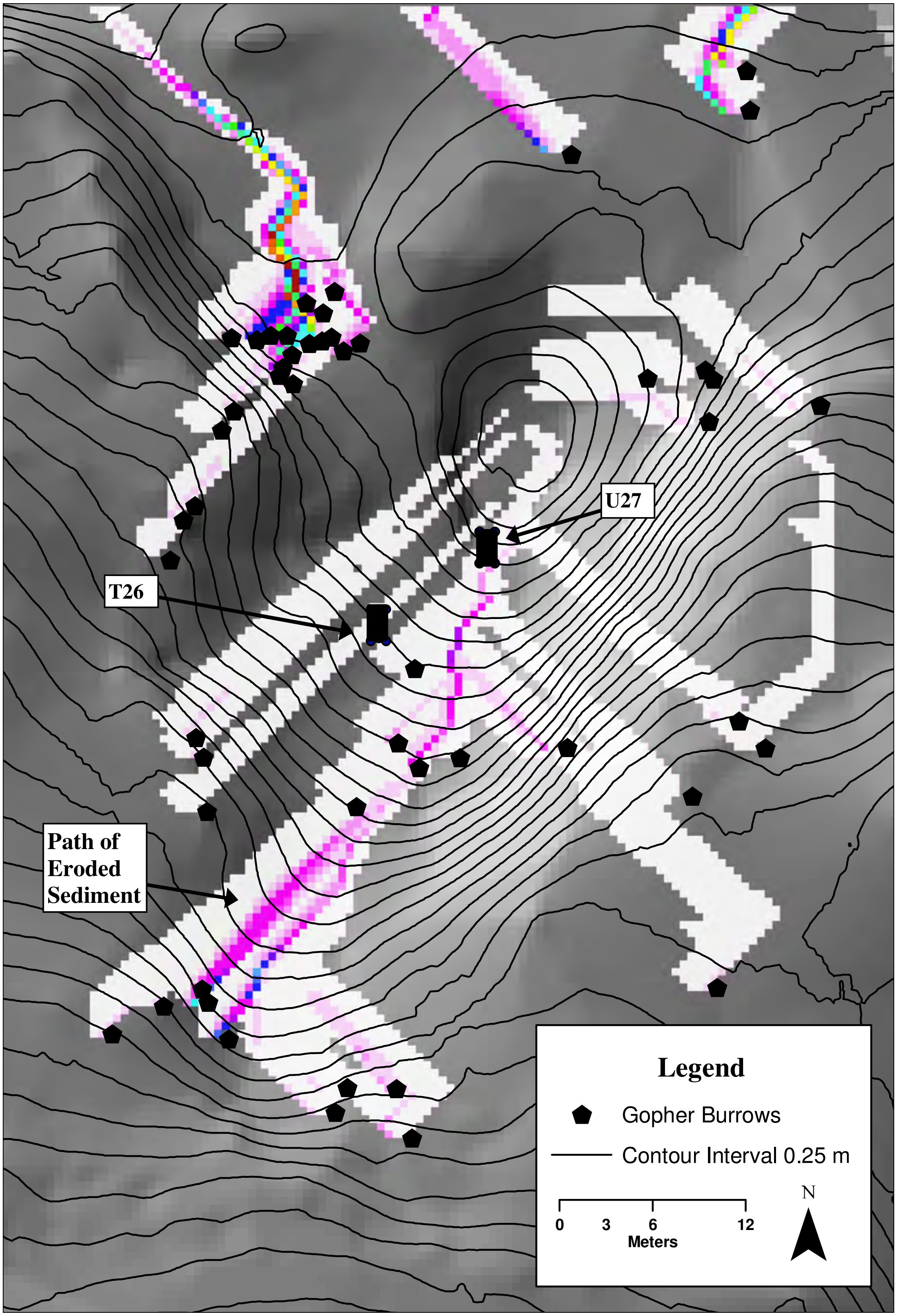
The D90 erosion model predicted that sediment eroding from the pocket gopher mounds and soil casts documented at the site would in fact reach the sag pond (Figure 4.6). Sediment accumulation was predicted to occur in U27-17 where three radiocarbon dated charcoal samples were collected. Table 4.11 shows the depth at which each sample was collected, the time range provided by radiocarbon dates, and the predicted amount of sediment accumulation associated with each date. The model over estimated the amount of sediment accumulation for sample U27-17-6, under estimated sample U27-27-11, and was relatively close to the real accumulation for sample U27-17-10.

Table 4.11. Radiocarbon Samples: Predicted and Actual Accumulation

Sample #	**Actual Depth**	**Radiocarbon Cal BP** (max)	**D90 Model**		**Radiocarbon Cal BP** (min)	**D90 Model**	
			Predicted	**Difference**		**Predicted**	**Difference**
U27-17-6	44 cmbs	2720	102 cmbs	+ 58 cm	2350	104 cmbs	+ 60 cm
U27-17-10	62 cmbs	2760	60 cmbs	- 2 cm	2760	56 cmbs	- 6 cm
U27-17-11	106 cmbs	3850	79 cmbs	- 27 cm	3640	74 cmbs	- 32 cm

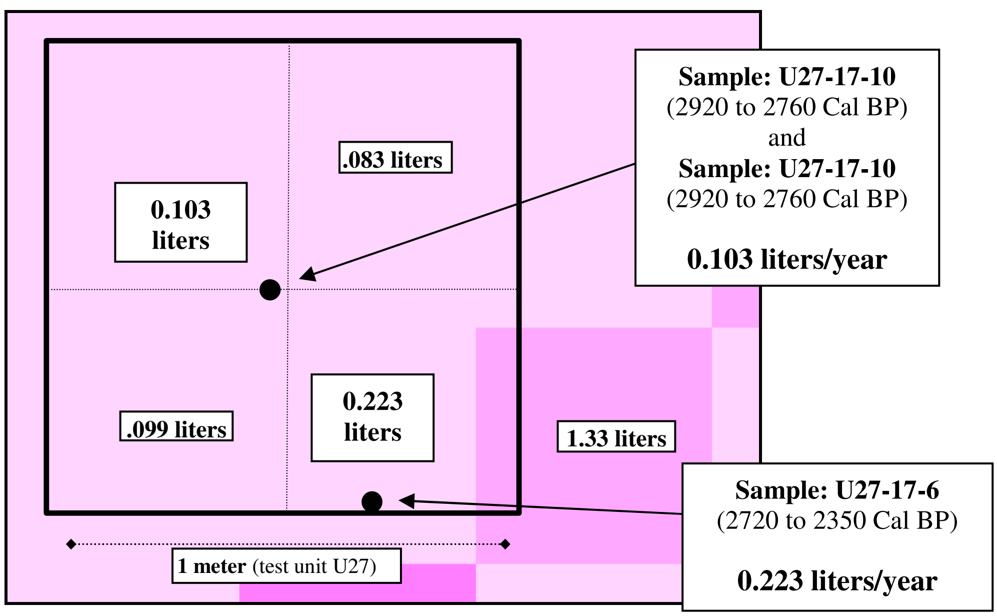
There are many factors that could influence why the model did not predict the amount of sediment accumulation actually found in the pond. One significant problem with the model is based on the data used in analysis. The high resolution elevation information collected in the field had to be merged with a smaller scale USGS DEM (1:24,000). As mentioned previously, a difference in the vertical datums used by the two maps was uncovered by comparing the difference in elevation between overlying grid cells.

Figure 4.6. Path of Erosion Predicted by D90 Erosion Model



The average difference between elevations in corresponding cells was calculated and the data adjusted. Small variation in elevation between adjacent grid cells will impact the results of the model as the algorithm terminates if a neighboring cell with a lower elevation is not encountered. This may cause predicted sediment movement to cease prematurely. The inconsistency in the amount of accumulation predicted per cell is shown in Figure 4.7. These differences seem small, however extrapolated out over thousands of years, as was done for this analysis, the discrepancies become very significant.

Figure 4.7. Predicted Sediment Accumulation at Sample Locations in U27-17



Another potential data-related issue involves the determining the depth from which radiocarbon samples U27-17-10 and U27-17-11 were collected. Sample U27-17-10 was obtained from screened sediment and U27-17-11 was collected from an auger probe that was placed in the center of the unit. For U27-17-10, the elevation of the ground surface prior to excavation and the ending elevation of the level from which it was collected (Level 12, 62 cmbs) were used to determine the amount of accumulation. Levels were excavated in 5-cm intervals and it is unknown where within those 5-cm the charcoal originated. U27-17-11, the sample obtained from the auger probe, has a slightly higher margin of error and could actually be 10 cm shallower what is used in the calculations. Sample U27-17-6 was collected *in situ* and there should be no significant issues with real verses estimated depth. Unfortunately, the model was least accurate for the *in-situ* sample.

The model is considering only one method of sedimentation; that which results from pocket gopher activity. There are likely many sources contributing and removing particulate pattern from the pond catchment. If the model had consistently predicted too low accumulation, it would not have been as problematic since gopher sediment should only account for a portion of the deposition. The over-sedimentation predicted for sample U27-17-6 can not be as easily accounted for.

The model assumes steady state conditions; that the gopher population recorded in 2006 represents gopher activity in perpetuity. The model does not account for fluctuation in the density of pocket gopher occupation, climate, shifts biotic comminutes, or terrain changes, all of which influence the intensity of erosion.

Summary

This chapter compared artifacts recovered from test excavation units, the site surface, and gopher disturbed sediment. Site formation processes were examined using the soil profiles of test excavation units, spatial analysis of burrow placement and their associated sediment characteristics, and a GIS-based erosion model. The following chapter analyzes the results, provides suggestions for additional work at 48PA2874, and discusses the broader application of pocket gopher research.

CHAPTER 5

IDENTIFYING PATTERNS:
POCKET GOPHERS, ARTIFACT DISTRIBUTION, AND EROSION

This research couples biophysical processes with archeological data to explore the influence of pocket gopher activity on site formation. Pocket gopher behavior in high elevation environments and geospatial analysis of burrow location were used to identify topographic controls on burrow placement. If gophers tend to occupy certain terrain, then cultural material located in these areas are more likely to be affected by gopher activity. To explore the influence of pocket gophers on artifact distribution the physical characteristics of chipped stone recovered from gopher-churned sediment, the undisturbed site surface, and subsurface artifacts were compared. Erosion from gopher mounds and soil casts was evaluated by comparing sediment characteristics in active and abandoned burrows and with a GIS-based erosion model.

Pocket Gopher Transportation of Surface Artifacts

The size and shape of chipped stone within gopher mounds and soil casts were indistinguishable from those located on the undisturbed site surface. Pocket gopher activity does not appear to be sorting surface artifacts by length, elongation, flatness, blockiness/angularity, or weight. However, a difference in artifact density was identified.

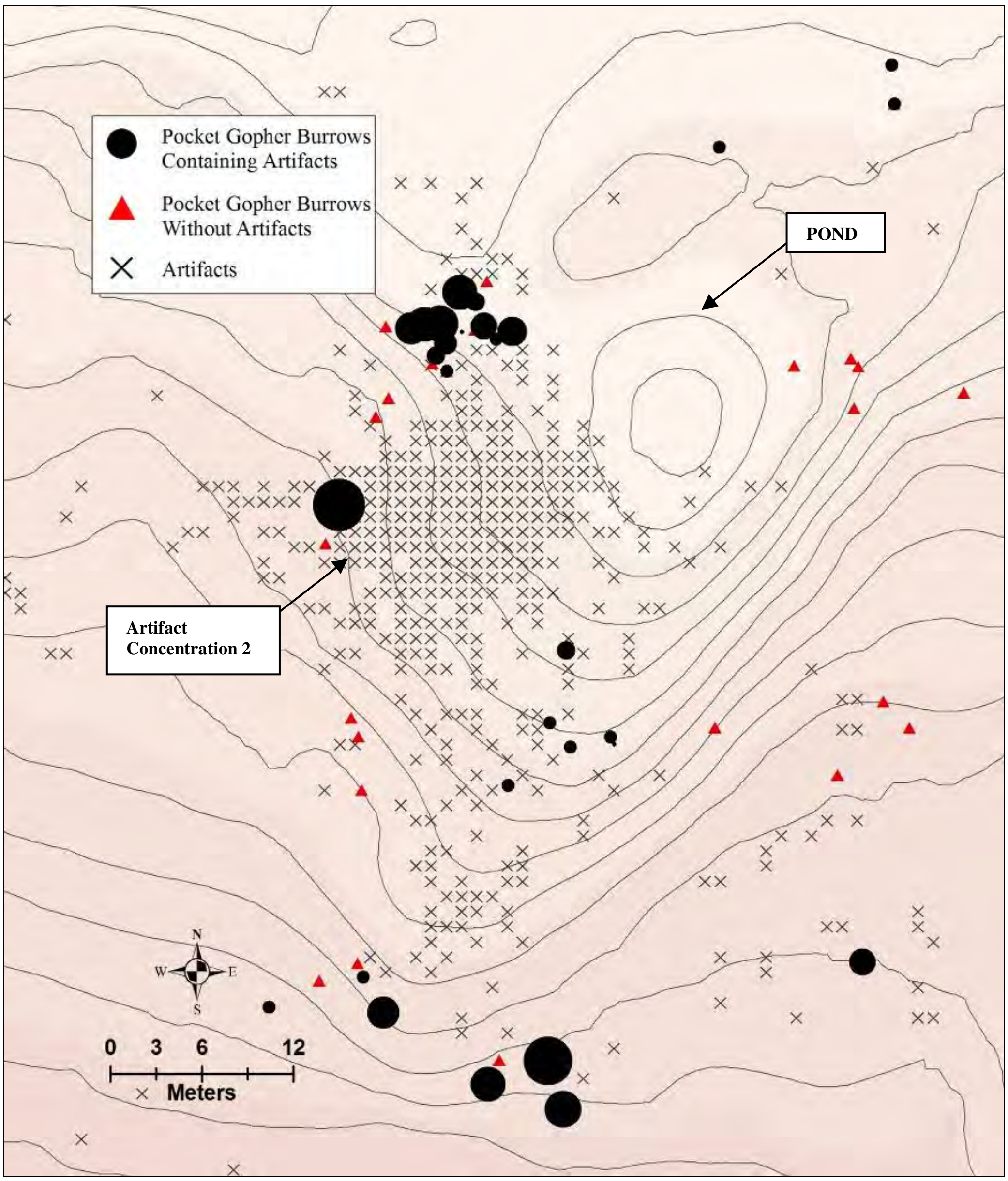
The average artifact density in gopher mounds and soil casts, obtained by dividing the number of artifacts within gopher sediment by the areal extent of disturbance (114 artifacts/28.8 m^2), is 4 artifacts/m^2. In contrast, average density of the site surface assemblage is less than 0.1/ m^2 (2,470 artifacts/28,000 m^2). This ratio may be misleading as the site is comprised of multiple artifact concentrations spread over a large area. It is more appropriate to compare the density of chipped stone in artifact concentrations with those in gopher burrows. The average density in Concentration 2, the concentration where pocket gopher activity was documented, is approximately 1/m^2 (769 artifacts/800 m^2). Although this is greater than the overall site assemblage, it is still notably lower than artifact density in gopher sediment. The localized impact of gopher activity was evaluated by examining density in 2, 4, 6, 8, and 10 m zones extending out from the gopher burrows. The raw artifact count increases from the 2 to 6 m analysis areas (Table 5.1). However, when surface area is taken into consideration, the inverse is true. Average artifact density decreases steadily from the 2 m zone outward.

Table 5.1. Average Artifact Density: Gopher Burrows and Site Surface

Location	# Artifacts	Area (m^2)	Artifacts/m^2
Gopher	114	28.2 m^2	4
0 – 2 m	74	166 m^2	0.45
2 – 4 m	131	499 m^2	0.26
4 – 6 m	225	832 m^2	0.27
6 – 8 m	210	1,165 m^2	0.19
8 - 10m	207	1,522 m^2	0.14
Site	2470	28,000 m^2	0.09

Although no spatial patterning by size or shape was observed on the surface of the site, the effect of pocket gopher activity on artifact density is not entirely clear. The average artifact density in pocket gopher burrows appears high when compared to undisturbed areas; and a trend where artifact density decreases with increasing distance from the burrow was identified. As shown in Figure 5.1, pocket gopher activity is patchy across the landscape and artifacts are irregularly distributed within mounds and soil casts.

Figure 5.1. Pocket Gopher Burrows and Cultural Material:
Size of Black Dot Indicates the Proportion of Total Artifacts Recovered per Burrow



Out of 53 mound and soil casts, just over half contained cultural material (n=29, 55%). Burrow sediment containing artifacts are more frequently located on the gentle slopes north, south, and west of the pond (Figure 5.1). No artifacts were recovered from mounds located on the steeper eastern slope.

Gopher disturbed artifacts tended to be located on the periphery of Concentration 2. This presents the following questions: Are gophers transporting surface artifacts horizontally, independent of shape or size, creating or diluting artifact distribution in Concentration 2? Does the displacement of surface artifacts facilitate lateral movement by other geomorphic processes, such as mass wasting, cryoturbation, or alluvial transportation? Is gopher activity impacting material already present on the site surface without significantly changing the spatial relationship? Can these interactions be recognized?

Lateral movement of artifacts has the potential to expand the boundaries of a site and lower the density of artifacts in one area while increasing density in a new location (Bocek 1992). As discussed in Chapter 2, Bocek (1992) documented the horizontal transportation of subsurface material by gophers, finding that artifacts 0.6 to 1.8 cm in diameter and non-cultural rock 1.8 to 3.5 cm were the most prone to lateral movement. The size variation in transported cultural and non-cultural material may be due to differences in density (mass), although this has not been conclusively demonstrated (Bocek 1986). While subsurface horizontal movement was found, no new cultural material was brought to the site surface during the seven-year study (Bocek 1992:267). It seems reasonable to assume that if pocket gophers are transporting artifacts horizontally beneath the ground, then continued activity would eventually eject the relocated subsurface cultural material onto the surface. The length of time needed for this process to become evident is not known.

Recognizing this process in the archaeological record is difficult. It is possible artifacts transported laterally underground before being relocated to the site surface would contain a higher frequency of artifacts 0.6 to 1.8 cm and natural rock 1.8 to 3.5 cm in length. Little variation in the length of chipped stone in gopher sediment was observed; 73% were located in the size range Bocek (1992) associated with subsurface lateral transport. In addition, the average length of surface artifacts at 48PA2874 was not statistically different than those in gopher sediment. Of the non-modified stone, only 14% were within the size range found at Jasper Ridge (Bocek 1992). The reason for this discrepancy is unknown; it may be a result of environmental differences.

To understand pocket gopher impacts to surface archaeological material at 48PA2874 it is recommended gopher occupation be documented across the entire site, with particular emphasis on gopher activity near the four other artifact concentrations. If a concentration with no evidence of gopher activity is found, then comparing the distribution of artifacts in the undisturbed concentration with those in Concentration 2 could provide information on formation processes. If gophers are expanding Concentration 2, then there may be observable differences in the density or the size and shape of chipped stone located on the periphery of the two concentrations. If gopher activity is causing, or contributing to the concentration of artifacts, there may be a similar discrepancy within the interior of the concentrations.

At this time, the distribution of surface artifacts at 48PA2874 is interpreted as resulting from human use rather than gopher activity. This is supported by clusters of heat-impacted artifacts within the larger concentrations. Although no fire-crack rock was found, clusters of heat-impacted chipped stone can indicate the presence of an intact hearth feature. Intact features suggest gophers have not been transporting surface artifacts. However, further analysis is needed to avoid inferring human behavior from an artifact distribution resulting from bioturbation.

Pocket Gopher Impacts on Subsurface Cultural Material

Surface and subsurface artifacts have statistically significant differences in at least one physical characteristic in every level of all four test units. Is disturbance by gophers causing the marked distinction seen in the size and shape of surface and subsurface chipped stone? To address this question, the vertical distribution of buried archaeological material at 48PA2874 was compared with three artifact distribution patterns attributed to gopher activity by Bocek (1986), Erlandson (1984), and Johnson (1989).

Before data from 48PA2874 can be compared to the results of other studies, the landscape characteristics of the current project area should be considered. The extent of pocket gopher activity will be influenced by soil depth, moisture, hardness, and rockiness (Beck 1965:4). The composition of vegetation communities and density is also a factor in gopher occupation (Romañach et al. 2005). Forbs and grasses, pocket gopher's primary food source in montane ecotones, are more abundant in the pond area due to the accumulation of water from snowmelt and protection from the drying winds. Test units were placed on a north-northeast facing slope; the aspect pocket gopher burrows were most commonly found. The test units were also within the most common elevation range (3097 m and 3099 m). Slope was not shown to be a factor in burrow placement; however the units were located between a gradient of 1º to 4º. The habitat suitability of test excavation areas had both positive and negative qualities. Based on environmental conditions, occupation of this area can not be ruled out.

Bocek (1986), Erlandson (1984), and Johnson (1989) all conducted research in California in areas with dense grasses, deep deposits, and notable soil development. Pocket gopher activity in these three studies areas can be expected to occur at a greater depth than at 48PA2874. At the current research site, deposits are more shallow and have undergone little pedogenesis. Like most high elevation environments, the amount of deposition across the site is highly localized.

Test excavation in the U27 units show sediment accumulation in the pond is much greater than the deposits upslope (T26). Pond sediment has a greater water content, more organic material, fewer gravels, and is less compacted than slope material. While unconsolidated material is favorable for pocket gophers, the seasonal influx of water from snowmelt makes continuous pocket gopher occupation in the pond area unlikely (Ingles 1948, 1952). However, if occurring, it would be expected that evidence of gopher activity could be as deep as 50 cmbs in the U27 units.

Pocket gopher activity upslope of the pond is expected to be much shallower than activity in the pond. Compared to deposition in the pond, the slope has relatively thin deposits. The upper strata overlays a more compacted mass of large clasts and gravels within a silt and clay rich matrix. This cobble layer, deposited by a slump-earthflow event, is not material conducive to burrowing (Johnson 1989). Clasts are dense and measure up to 25 cm in length. As discussed previously, pocket gophers typically avoid material larger than 5 cm (Bocek 1986). The density of large rocks, the compactness of the deposit, and the presumed depth of the slump-earthflow material would make burrowing around or under the layer impossible. Therefore, gopher activity on the slope above the pond is not expected to occur beneath the upper horizon of sediment, between 15 cmbs at the shallowest point in the T26 units and at least 30 cmbs where the landslide deposit was not reached during excavation. Compared to other species of pocket gophers, *Thomomys* has been shown to inhabit comparatively thin, rocky soils (Beck 1965:5); therefore, it is not unreasonable to suspect gophers would burrow in the shallower sediment along the slope. Activity is more likely to occur where the deposits overlaying the slump-earthflow material is thickest. This would be in unit T26-6, located downslope of T26-7, where there is greater sediment accumulation.

Evidence of Pocket Gopher Occupation in the Test Units

Evidence of pocket gopher occupation on the ground surface near the test excavation units was minimal. One mound was documented three meters southeast of the T26 units. No gopher mounds or soil casts were adjacent to U27, however there was a surface opening with little associated loose sediment in U27-17. Subsurface indications of past gopher activity can be recognized by the presence of krotivina, changes in sediment color and texture that result from the infilling of tunnels (Erlandson 1984), or from the accumulation of fecal pellets or organic material at the depth of dens and food caches (Ingles 1949, 1952). No subsurface evidence of gopher activity was noted during test excavation in any unit. Below the layer of sod in U27 no indications of gopher activity were reported.

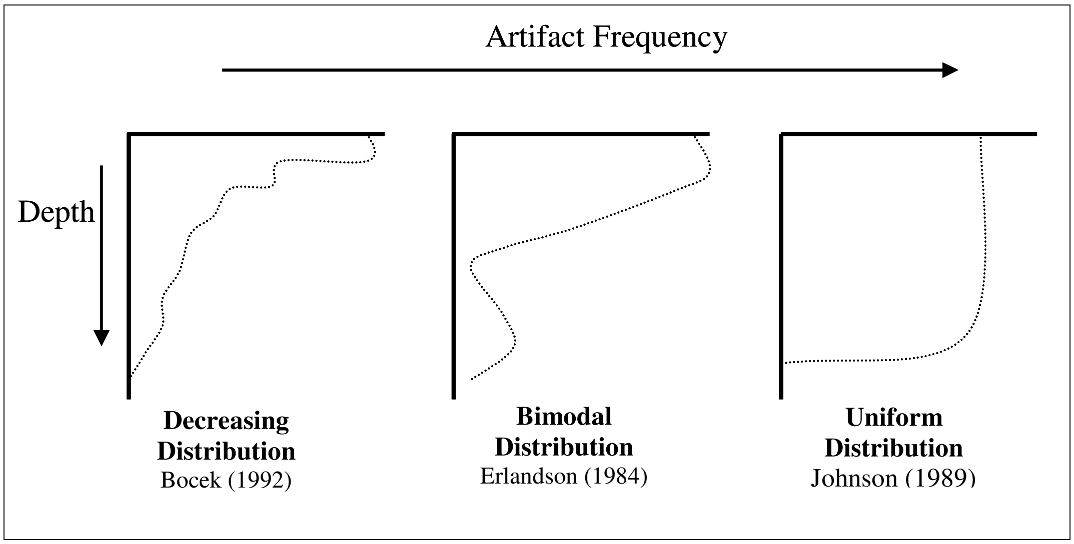
48PA2874 and Previous Archaeological Research on Pocket Gophers

As discussed in Chapter 2, Bocek (1986) and Johnson (1989) found pocket gopher activity resulted in the stratification of artifacts and non-cultural material by size. Bocek's initial excavation at Jasper Ridge, found that lithic debris between 0.6 and 2.5 cm in size were disproportionally present in the upper 30 cmbs (Bocek 1992:262). Artifact frequency had a distinct trend with the largest number of artifacts in the first 10 cmbs and decreasing steadily thereafter (Figure 5.2). Artifacts larger than 5 cm were concentrated around 50 cmbs, the typical extent of gopher activity at Jasper Ridge, below which very few artifacts were encountered (Bocek: 1986:595,596). Johnson (1989:370) refers to the layer of randomly oriented clasts accumulating below pocket gopher tunnels and burrows as 'stone zones'.

While Johnson (1989) and Bocek (1986) both encountered an increase in the size of artifacts at the maximum depth of gopher activity, there was a difference in the overall distribution of archaeological material. Johnson (1989) found smaller artifacts were evenly dispersed throughout a thick homogenized biomantle lying above the stone zone (Figure 5.2). In addition, the material comprising stone zones measured a minimum of 6 to 7 cm, slightly larger than that discovered by Bocek (1986).

Erlandson (1984) discovered a very different pattern in artifact distribution with pocket gopher disturbance. He speculated that the infilling of collapsed tunnels and burrows were creating a weakly bimodal pattern in artifact frequency by depth (Figure 5.2). Bocek (1986) analyzed Erlandson's data and found that the largest artifacts were located from 0 – 20 cmbs and that the difference between artifact size in the upper and lower strata (0 – 40 and 40 – 70 cmbs) was not statistically significant at the alpha 0.05 level (Bocek 1986:600).

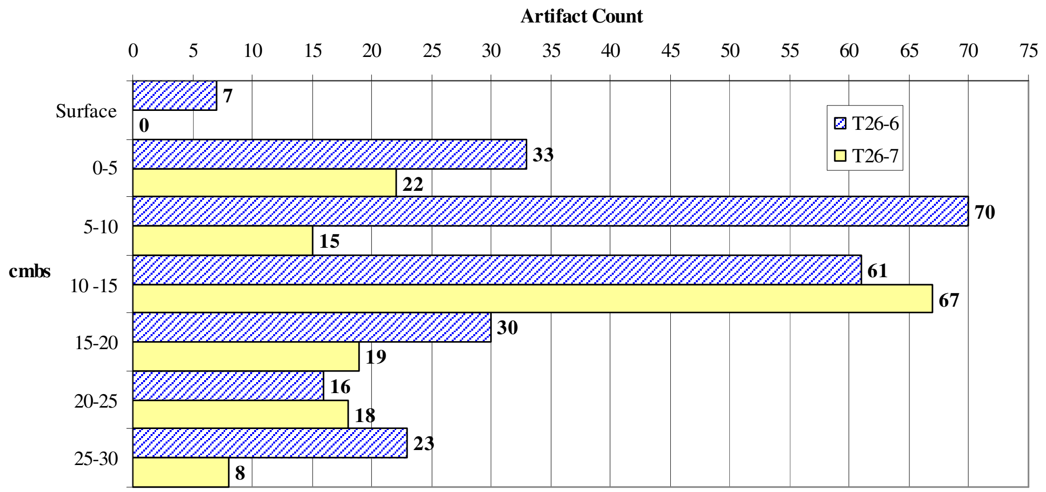
Figure 5.2. Three Different Patterns of Subsurface Artifact Distribution Attributed to Gopher Activity



None of the four test units excavated at 48PA2874 reached sterile horizons due to time limitations. The following discussion is based on an incomplete record of the extent of buried cultural material. Artifact frequency by depth in T26-7 was unimodal, not consistent with any of the previously identified patterns (Figure 5.2, 5.3a). As shown in Figure 5.3a and 5.3b, units T26-6, U27-16, and U27-17 appear to have a bimodal distribution of artifacts. However the second 'peak' in U27-16 consists of only one additional artifact. Artifact frequency is more strongly bimodal in U27-17, but like U27-16 the increase in artifacts is small (n=4). Within the 60 cm of sediment excavated in the 1 by 1 m unit, only 44 artifacts were recovered. It is possible the low number of total artifacts recovered from U27-17 makes this seemly minor increase more significant. While the high moisture content of pond sediment does not favor pocket gopher occupation (Ingles 1948), U27-17 was the only unit to have surface evidence of pocket gopher activity.

Figure 5.3. T26 and U27: Artifact Frequency by Depth
a. Units T26-6 and T26-7; **b.** Units U27-16 and U27-17

a.



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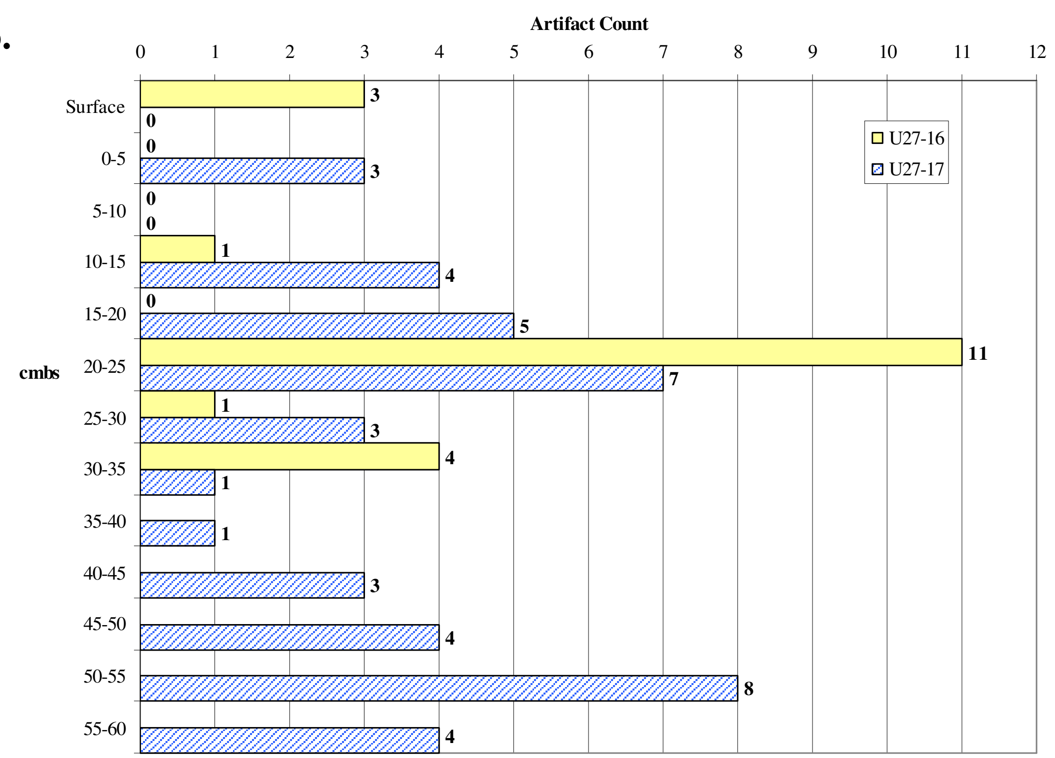


The second peak in T26-6 (n=6) occurred in the final level excavated, therefore it is not known if frequency would continue to increase, decrease, or remain steady. The distribution pattern is also unknown in U27-16 and U27-17; however both units were excavated one level below the second peak in frequency, which better supports the potential for a bimodal distribution of cultural material.

The vertical distribution of artifacts in T26-6, U27-16, and U27-17 follow more closely with the distribution pattern identified by Erlandson (1984) than either Bocek (1992) or Johnson (1989). However the relationship is not strong. Artifacts in T26-7 were not consistent with any previously identified distribution patterns. In the units with a bimodal trend the depth of the second peak in artifact frequency does correspond to the maximum depth of pocket gopher activity expected in each unit. It is difficult to identify patterns in distribution when the extent of subsurface cultural deposits is undetermined. Before any conclusions can be drawn, units need to be further excavated to determine if additional cultural material is present.

Artifact Size in Gopher Burrows and Test Excavation Units

The size of artifacts in T26 increases near the depth of maximum gopher activity (25 cmbs in the T26 units). Statistical analysis indicates the mean length of artifacts recovered from 0 – 10 cmbs is significantly smaller than those from 15 – 25 cmbs at the alpha 0.05 level (Appendix B). However, the average length of material found from 15 – 25 cmbs (11 mm), is within the size range transported by pocket gophers (Bocek 1986). A clear relationship between artifact length and depth in the T26 units can not be attributed gopher activity.

If pocket gopher activity was dispersing material of a particular size-grade throughout the upper layer of the soil profile, as found by Johnson (1989), it can be assumed that the same size material would be found on the ground surface. However, this is not the case. Artifacts located on the surface of T26 are significantly larger than subsurface material at all depths. The mean length of artifacts from 0 – 5 cmbs and 5 - 10 cmbs (the burrowing zone) is uniform, supporting Johnson's (1989) findings, assuming the burrowing zone at T26 is between 0 – 10 cmbs as expected.

A connection between artifact size and depth was not identified in the U27 units. Neither size stratification nor frequency distributions found by Bocek (1986) or Johnson (1989) were strongly represented in the T26 units. There is a general trend with smaller artifacts located 0 – 10 cmbs and larger material at the maximum depth of burrowing (25 cmbs). However, as stated above, the larger material is within the size that gophers are capable of transporting.

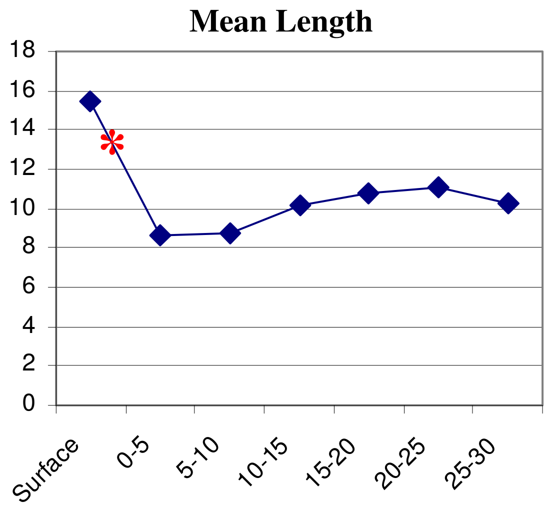
The shape indices elongation, flatness, blockiness/roundness, and weight were also evaluated for patterns in vertical distribution. If pocket gopher activity is causing the stratification of artifacts based on physical characteristics, artifacts within the zone of burrowing (from 0 - 10 cmbs in T26) are expected to have uniform properties, shifting at the maximum depth of burrowing. *T*-tests comparing artifacts recovered from 0 – 5 cmbs with those from 5 – 10 cmbs indicate there is no statistical difference in the any of the attributes examined, conforming to Johnson's (1989) findings.

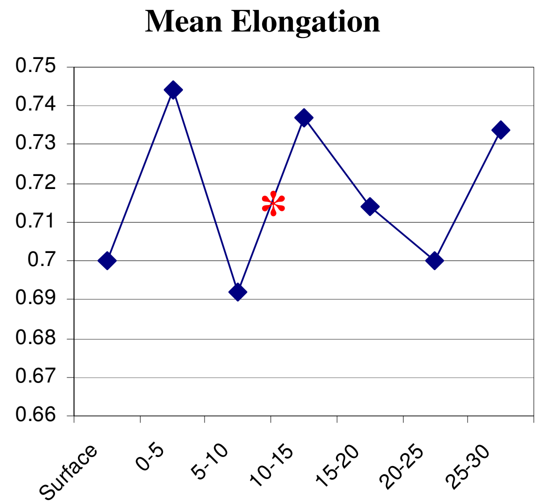
With the exception of elongation, the mean values of artifact characteristics plotted by depth generally display a wave-like distribution (Figure 5.4). Surface artifacts are notability different than those from 0 – 5 cmbs. Surface cultural material is longer, less flat, more rounded, and heavier. From 0 – 20 cmbs length gently increases and artifacts become less flat. Length decreases from 25 – 30 cmbs and artifacts become more flat from 20 – 25 cmbs, then less flat 25 – 30 cmbs. Artifacts become more angular 0 – 10 cmbs, more rounded 10 -15 cmbs, more angular 15 – 25 cmbs, and more round at 25 cmbs. Weight increases from 0 – 10 cmbs and then remains steady. There does not appear to be a pattern in the elongation values by depth. Not all of the characteristics between levels are statistically significant at the alpha 0.05 level (Figure 5.4). Detailed results of statistical analysis comparing each level are located in Appendix B.

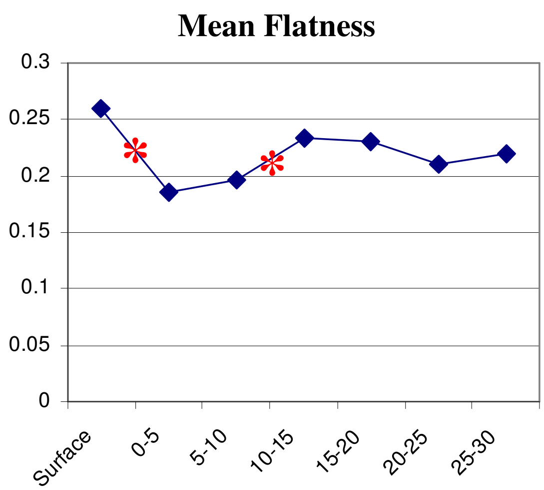
Pocket Gophers and Erosion at 48PA2874

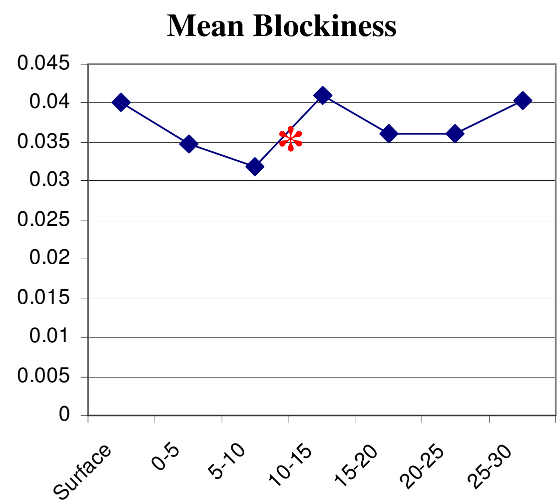
One goal of this analysis was to examine the extent of erosion occurring from pocket gopher disturbed sediment. Particle size analysis indicates the proportion of clay in inactive and active burrows is statistically different. This supports the proposal inactive burrows, assumed to have been exposed on the ground surface longer than active burrows, have a lower proportion of small, easily eroded particles. There were not statistically significant differences at the alpha 0.05 level in silt or sand in active and inactive burrows. It should be noted that sand misses the zone of significance by only 0.008 ($p = 0.058$).

Figure 5.4. Mean Values of Artifact Characteristics by Depth



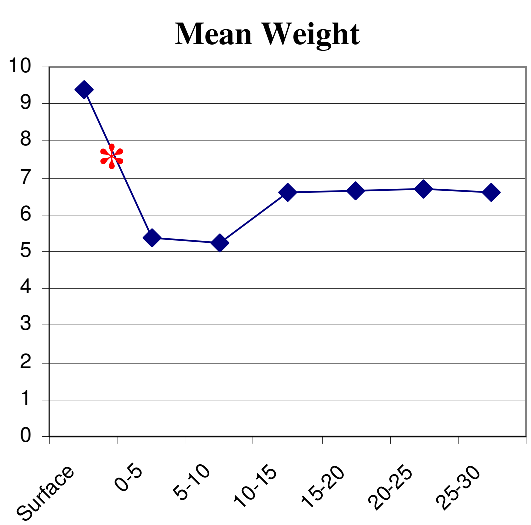






Average value of artifact characteristics by depth in unit T26.

Asterisks between depths (cmbs) indicate statistical significance between the two levels at the (alpha 0.05 level).



The topographic location of burrows appears to influence the percent of sand, silt, and clay in gopher-disturbed sediment. There is a higher percent of sand in burrows on hill tops and on the steeper slopes than in lower gradient areas. Mounds and soil casts located on higher elevation, exposed portions of the landform are susceptible to deflation by wind and steep slopes facilitate mass wasting.

If gopher disturbed sediment is being transported, where is it being deposited? The D90 erosion model sought to address this question by predicting the path and amount of sediment eroding from the pocket gopher mounds. While the model did indicate sediment would be deposited in the pond catchment, the predicted accumulation only corresponded with one of the three radiocarbon dated samples collected from known depths during test excavation. As discussed in Chapter 4, there are potential problems with the elevation data and with the fundamental assumptions underlying the model. The accretion and removal of sediment is part of a dynamic system with positive and negative feedbacks that operate continuously on multiple scales. Models attempt to whittle down these complex interactions to manageable components. As a result, they are not representative of the real world. The D90 model focused on the transportation of sediment by overland flow, not considering other methods, such as wind, freeze-thaw, soil creep or other types of mass movements, and infiltration. Bioturbation interacts with each of the drivers of sediment transportation; meaning, even if overland flow dominated erosion, this process can facilitate aeolian processes, cryoturbation, gravitational movement, and infiltration. Micro-environmental features, such as rocks downslope of sediment movement, small topographic differences, and variation in vegetation coverage were not included in the model. One of the most significant problems is that gopher occupation, climate, and terrain features in the model remain steady throughout time, an obviously false assumption.

Future Research Directions

This research aimed to address four questions: 1) Is pocket gopher activity affecting the horizontal or vertical distribution of cultural material in an observable and predictable manner? 2) Do pocket gophers inhabit particular topographic features, allowing archaeologists to anticipate areas with a high probability of disturbance? 3) How does disturbed sediment affect geomorphic processes, specifically erosion at the site? 4) Does a GIS based model predicting erosion from pocket gopher mounds and soil casts indicate sediment will be deposited in the sag pond? If so, does the amount of sediment accumulation in the sag pond correspond to accumulation calculated from radiocarbon dated samples? The following section will describe additional site-specific research that could be done to further address these research questions.

Understanding Pocket Gophers and Artifact Transportation

Pocket gopher impacts on the distribution of surface and subsurface archaeological material at 48PA2874 could be better understood with further documentation of pocket gopher activity. Analyses indicate potential trends in distribution. These patterns need to be further examined prior to concluding that gopher activity is, or is not, transporting cultural material. It is recommended the following research on surface material be conducted at the site:

Site-Specific Research: Surface Documentation

1. Record mound and soil cast attributes and map gopher activity across the entire site to further evaluate the influence of gopher disturbance on artifact density and sorting of artifacts by physical characteristics.
2. Map the shape of areal disturbance of mound sediment and the orientation of soil casts. With these data, disturbed areas can be looked at in relation to topographic features, in particular slope.
3. Create a high resolution topographic map for the entire site surface using a systemic mapping method and run the D90 erosion model with the new data.
4. Document vegetation type and changes in composition or density across the site during Spring, the height of gopher activity. This can be linked with burrow location to identify preferences in pocket gopher habitat based on vegetation communities.
5. Visit the site at regular intervals over multiple seasons and collect the following information:
    a. Map the areal extent and depth of snow cover during each site visit.
    b. Document and map evidence of gopher activity as it becomes exposed by snowmelt and as new mounds form. This will determine how long gopher disturbed areas have been exposed to erosion and if there are seasonal changes in the location of gopher occupation.
    c. Collect mound and soil cast sediment samples throughout the season to identify changes in particle size.

d. Place sediment collection troughs downslope of gopher mounds/soil casts at multiple distance intervals to examine transportation of sediment over the ground surface (similar to the study conducted by Sherrod and Seasted 2001 discussed in Chapter 2).

Site Specific Research: Subsurface documentation

Subsurface archaeological material did not have a strong correlation to the vertical distribution found by other researchers (Bocek 1986; Erlandson 1984; Johnson 1989). However, the limited amount of test excavation conducted could not provide a complete picture of the vertical distribution of cultural material. It is recommended the following research on subsurface material be conducted at the site:

1. Excavate the backfilled sediment in U26-16, 17 and T26-6,7 to search for evidence of new gopher activity and newly introduced chipped stoned (similar to Bocek's 1992 research at Jasper Ridge).
2. Continue test excavation of the units to determine the extent of subsurface cultural material and the depth of slump-earthflow deposits.
3. Excavate beneath gopher mounds and soil casts to examine artifact distribution in areas with known gopher disturbance.
4. Excavate areas exhibiting no evidence of gopher activity on multiple landform features.
5. Collect additional samples for radiocarbon dating and evaluate the estimated sediment accumulation with the deposition predicted by the D90 erosion model.

Like most research, this project raises more questions then it answers. Documentation of gopher activity across the entire site will help evaluate the relationship between disturbance areas and chipped stone. Knowing the location of pocket gopher burrows across a wider geographic area would help identify environmental factors influencing burrow placement. A high resolution topographic map and the locations of gopher activity across the site would allow for additional testing of the erosion model.

Subsurface testing should be expanded at the site. Test units were focused on the pond catchment area, only one of many topographic features at the site. To understand the relationship between the vertical distribution of artifacts and gopher activity across the landform test units should be placed in other areas of the site. Test excavation in locations with known gopher activity may help identify the influence of gopher activity on the vertical distribution of artifacts.

While the impact of pocket gopher activity on the lateral and vertical movement of artifacts at 48PA2874 could not be determined information was gained from the study. Primarily, this project has provided a general background that may spur additional research. With further study the effect of pocket gopher activity on artifact distribution in high elevation environments can be better understood.

Pocket Gophers, Geomorphology, and Archaeology: A Regional Perspective

The interaction of pocket gophers, geomorphic processes, and cultural material can not be understood through the study of a single site. There is a lack of published archaeological research on pocket gopher impacts to artifacts. At present, three pocket gopher-specific studies dominate the archaeological literature, Bocek (1986, 1992), Erlandson (1984), and Johnson (1989). These three studies were conducted in the coastal foothills of south-central California, a vastly different environment than the high elevation, alpine grassland of this study. Although research at 48PA2874 is just beginning, initial results show little similarities with the studies from California. Can these differences be attributed to environmental factors, such as soil characteristics, climate, or topography? Are the anatomical and behavioral patterns of the two pocket gopher species, *Thomomys bottae* (California) and *Thomomys talpoides* (current project) causing different affects on archaeological material? If so, then identifying pocket gopher disturbance or modeling the impact of gopher activities could vary considerably between environments.

To further investigate this phenomenon, it is proposed that pocket gopher activity in archaeological sites be recorded in multiple settings, beginning with the variety of ecotones located in the GRSLE project area. Using the research methods suggested for further work at 48PA2874, sites containing pocket gopher activity should be documented in the low-elevation Greybull River basin, the mid-elevation forested areas, the subalpine – alpine transition zone, and the alpine mountain tops. Importantly, the lack of pocket gopher activity at sites should be noted as well.

Pocket gopher activity has the potential to impact not only individual sites, but also the regional history of an area. If pocket gophers in mountain settings occupy a particular habitat and their behavior alters the distribution of cultural material enough to change the interpretation of a site, then the understanding of sites within those environmental zones may be skewed. Since individual sites are the foundation of a regional understanding of prehistoric land use, it is crucial to determine the processes that may obscure or alter the interpretation of even a single, seemingly inconsequential site.

Pocket gopher documentation in a variety of settings would help form a better understanding of impacts to artifacts in differing environmental conditions. Eventually, information from the GRSLE project area could be expanded over a broader geographic coverage, examining not only the influence of environmental conditions but different pocket gopher species as well.

Pocket Gophers as Ecosystem Indicators

Pocket gopher occupation is important not only to the interpretation of archaeological sites but it can be used as a proxy for past environmental conditions. Had the erosion model accurately predicted the amount of accumulation occurring at 48PA2874, the information could have been used to examine long-term environmental change (Hall and Lamont 2003:220). Sediments are transported and deposited in particular environments and climatic conditions, and therefore, can yield valuable paleo-environmental information (Hassan 1978; Millar 2006). As pocket gophers can occupy a specific area for significant periods of time, they have the potential to provide archaeologists with a long record of environmental data. Deposits at Lamar Cave, a paleontological site in Yellowstone National Park contain a continuous record of *Thomomys talpoides* occupation spanning over 3,200 years. The study showed the density of pocket gopher population changed with fluctuations in climate, increasing during mesic periods and decreasing during xeric conditions (Hadly 1997). A similar trend may be seen in sedimentation rates or in the intensity of gopher occupation at an archaeological site.

Pocket Gophers and Site Management

How can pocket gopher studies be applied in a practical manner to archaeological site management and evaluation? The presence of artifacts in the mounds of subterranean animals has long been used by archaeologists to identify the presence of buried cultural deposits without further damaging a site with test excavation. While this is generally a legitimate practice, there is the potential that buried cultural deposits are created by the relocation of surface artifacts into gopher burrows. Therefore a radiocarbon date associated with a particular stratum may not be contemporaneous with the associated artifacts. If the affect of pocket gopher activity results in a predictable, observable distribution of artifacts, then this information could be used to identify sites impacted by subsurface faunalturbation and avoid misinterpreting site function.

Summary

The material record of past human activity is an interactive composite of cultural, biological, and physical processes. This project integrated biophysical research and archaeological data to examine site formation at 48PA2874. The study represents a preliminary step toward developing a better understanding of pocket gophers effects on sediment and cultural material in montane environments. Pocket gopher activity is important not only to the interpretation of individual sites, but can contribute to the regional archaeological record and a better understanding of human use of alpine environments. However, before behavioral inferences can be drawn from any archaeological site, post depositional changes to cultural material must be considered. Further research will help researchers judge the intensity of impacts to artifacts and begin to predict areas likely to be disturbed by subsurface faunalturbation. While pocket gophers may change the distribution of archaeological material, they should not be viewed as a destructive agent but rather as another factor in the taphonomic history of a site and the source of additional data. Clearly, the relationship of pocket gophers, geomorphic processes, and cultural material in alpine environments is complex. However, these interactions are fundamental to recognizing the full research potential of an archaeological site and developing a comprehensive, unbiased understanding of regional prehistory.

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APPENDIX A

APPENDIX A:

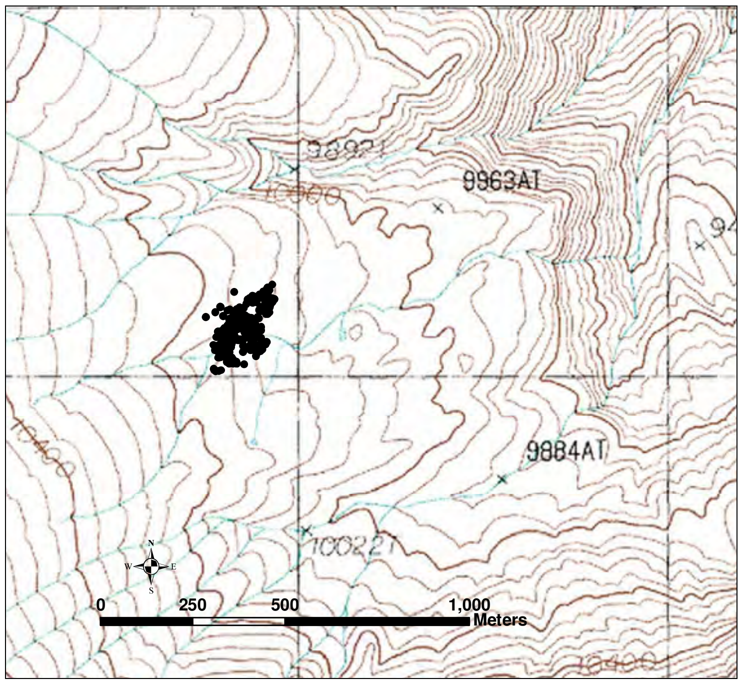
28PA2874 Site Data

Site 48PA2874 is located at the sub-alpine-alpine transition zone in an open upland meadow. The hummocky grassland overlooks the floodplain of the Greybull River to the east and is bounded on the north and east/southeast by steep drainages (Figure A.1). The undulating topography present today was formed over thousands of years by landslides and slump events caused by changes in moisture and temperature regimes. Overtime erosion has softened these features into multiple lobate-shaped slopes, many of which terminate in seasonally filled sag ponds. The entire area is dissected by shallow drainages and gullies.

Figure A.1. 48PA2874: Site Overview

Site 48PA2874 contains over 2,470 lithic artifacts covering 2.8-hectares. The site is located on the southern portion of the landform on a north and northeast facing toe slope. The site is significantly larger and contains a greater number and diversity of artifacts than other sites in the area.

Figure A.2. Map of 48PA2874:Lobate Slopes Bounded by Steep Drainages



The assemblage is dominated by flakes and angular debris, 96.5% (n=2385). Tools (worked flakes, bifaces, awls, scrapers, and projectile points) comprise 3% (n=75) of the artifacts at the site, nodules and cores make up 0.5% (n=11). Cortex was present on only 3.1% (n=77) of artifacts. When present, artifacts with 50% or more cortex account for a mere 0.7% (n=16) of the assemblage. There are 117 artifacts with evidence of heat exposure (4.8% of 2463 artifacts, heat impact data was missing for eight artifacts). Heat altered artifacts are clustered within concentrations of lithic debris, as described below. There are six artifact concentrations at 48PA2874.

Of the 75 tools found at the site, there were 16 worked flakes, 20 bifaces, 3 awls, 10 scrapers, and 26 projectile points. Over 80% of tools were located within artifact concentrations. Projectile points make-up 36% of the tool assemblage and temporally diagnostic points from all cultural periods have been found on the site surface. These include two Paleoindian (8%), two Early Archaic (8%), four Middle Archaic (15%), six Late Archaic (23%), four general Archaic (15%), two Late Prehistoric (8%), and six unidentifiable projectile points (23%).

Table A.1. Summary of Surface Artifact Data

a. Artifact Types

Artifact Type	Count	Percent
Flake	1806	73.1
Worked Flake	16	0.6
Edge Damage Flake	463	18.7
Angular Debris	116	4.7
Projectile Point	26	1.1
Biface	20	0.8
Scraper	10	0.4
Awl	3	0.1
Core	4	0.2
Nodules	7	0.3
Total	2471	100

b. All Tools

Tool Type	Count	Percent
Worked Flake	16	18.2
Biface (stage undetermined)	1	3.6
Biface Stage 1	1	0.9
Biface Stage 2	5	6.4
Biface Stage 3	7	7.3
Biface Stage 4	4	5.5
Biface Stage 5	2	7.3
Projectile Point	26	36.4
Scraper	10	11.8
Awl	3	2.7
Total Tools	75	100

c. Heat Impacted Artifacts

Type	Count	%
Crazing	51	2.1
Pot Lids	20	0.8
Multiple Types	12	0.5
Thermal Fracture	34	1.4
Absent	2346	94.9
Unspecified	8	0.3
Total	2471	100

d. Percent Cortex Present

Cortex	Count	%
0%	2394	96.9
1-10%	23	0.9
10-25%	21	0.8
25-50%	17	0.7
50-75%	9	0.4
75-100%	7	0.3
Total	2471	100

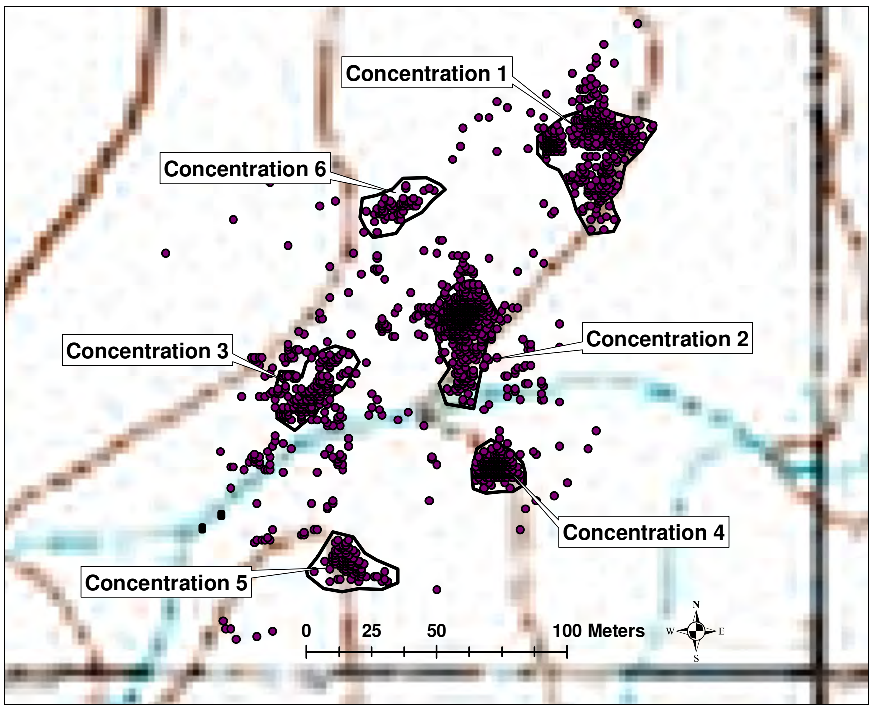
e. Projectile Point Types

Time Period	Count	%
Paleoindian	2	8
Early Archaic	2	8
Middle Archaic	4	15
Late Archaic	6	23
Archaic	4	15
Late Prehistoric	2	8
Unidentifiable	6	23
Total	26	100

Artifact Distribution

There are six discrete concentrations of artifacts separated by a sparse scatter of lithic material. The concentrations are located on two lobate slopes separated by a shallow drainage. Artifacts are located within a 25 m elevation range (3081 m to 3106 m) on a gradient ranging from 3 to 23%.

Figure A.3. Location of Artifact Concentrations



Concentration 1

Concentration 1 is located in the northern portion of the site and measures 65 m N/S by 43 m E/W. The concentration contains over 550 pieces of chipped stone including four projectile points, three bifaces, two awls, one worked flake and two tested chert nodules. The two chronologically diagnostic projectile points indicate Late

Prehistoric and Late Archaic occupation. Two projectile points date to general Archaic period and one was too fragmented to be identified. The western portion of Concentration 1 has a discrete cluster of heat impacted artifacts. With the exception of the single worked flake and one early stage biface, all tools in Concentration 1 are located outside the cluster of heat impacted artifacts. Notably, only expedient tools were found within the heat cluster. The limited time and effort invested in constructing these tools may have influenced the method of discard. Although concentrations of heat impacted artifacts often indicate the presence of a hearth, further investigation, such as excavation, is needed to determine if a feature is indeed present.

Concentration 2

Concentration 2 is located in the central portion of the site and measures 57 m N/S by 37 m E/W. The concentration surrounds the pond where pocket gopher documentation and test excavation was conducted. Approximately 800 artifacts are located in Concentration 2, including eight projectile points, seven bifaces, one core, three worked flakes, five scrapers, and two nodules. The only two projectile points found at 48PA2874 which date to the Paleoindian period are located in Concentration 2. One of the Paleoindian points could be specified as Agate Basin. Other diagnostic projectile points in Concentration 2 include two Middle Archaic, two Late Archaic, one general Archaic, and one temporally unidentifiable project point. The distribution of tools displays an interesting pattern. The four projectile points dating to the Archaic period are clustered in a 10 m^2 area with the Middle Archaic points lying directly beside one another. The Paleoindian points are located 15 meters apart. With the exception of the

Agate Basin and the unidentifiable projectile point, all projectile points are located within a cluster of heat affected artifacts. However, none of the projectile points have any indication of heat exposure. Other tools contained in the cluster of heat impacted artifacts are three bifaces, four scrapers, three worked flakes, and one nodule. Of these, only one tool, a worked flake, shows evidence of heat exposure. As in Concentration 1, a cluster of heat impacted artifacts may indicate a hearth feature but further work is needed.

Concentration 3

Concentration 3 is located in the western portion of the site and contains over 175 artifacts in a 30 m by 30 m area. Tools include six projectile points, one end scraper, one worked flake, and two bifaces. With the exception of one unidentifiable projectile point, all date to the Archaic period, one Early Archaic, two Middle Archaic, and two Late Archaic. Heat altered artifacts are scattered throughout the concentration.

Concentration 4

Concentration 4 is located in the southeastern portion of the site and measures 25 m^2. The concentration contains approximately 450 artifacts, including two projectile points, one biface, two scrapers, two worked flakes, and three nodules. The projectile points date to the Late Archaic and the general Archaic periods. A cluster of heat impacted artifacts are located within the concentration. The biface, scrapers, and worked flakes are located within this cluster of heat impacted.

Concentration 5

Concentration 5 is located in the southern portion of the site. The concentration is the smallest at the site measuring approximately 20 m^2. The concentration contains slightly over 100 artifacts. Only one tool, a worked flake, and two heat altered flakes were documented.

Concentration 6

Concentration 6 is located in the northwestern portion of the site and measures approximately 30 m E/W by 20 m N/S. The concentration contains approximately 50 artifacts including one Late Prehistoric projectile point, three bifaces, an awl, a worked flake, and a core. Only two heat affected artifacts were located in the concentration.

Interspersed around the concentrations are a scattering of flakes and a small number of tools. Only nine artifacts with evidence of heat exposure are present outside of the clusters, supporting the possibility these features are the remains of hearths.

Source of Tool Stone

Artifacts manufactured from both locally available and raw materials from distant sources are present at 48PA2874. In the following discussion 'local' is defined as being available in the Upper Greybull watershed. Toolstone locally available consists of Irish Rock chert, Madison Formation chert, Dollar Mountain Chert, chalcedony, petrified wood, mudstone, and volcanic material/basalt. Non-local source materials include a variety of cherts, quartzite, Morrison Formation quartzite, obsidian, porecelanite, and phosphoria. Quartzite and phosphoria can be obtained in the Big Horn Basin, east of the project area. Morrison Formation quartzite is available on the western side of the Big Horn Mountains (Bohn 2007:72). Much of the chert located at the site could be not visually be identified by crew members as either local or exotic as similar specimens can occur in both places. Therefore the majority of chert artifacts are classified as having an undetermined origin. Obsidian is not available locally, but like chert is available in multiple locations. For her Master's thesis completed in 2007, Allison Bohn analyzed the source of obsidian artifacts throughout the GRSLE project area. A small portion of her study involved 12 obsidian samples from 48PA2874 (Bohn 2007:98). The results relevant to this study are discussed below.

Over half the artifacts (67%) at 48PA2478 are comprised of chert that can not been identified to source location. Artifacts from local raw material make up 21% of the assemblage, non-local material 11%. The high proportion of unidentifiable sources makes inferring information such as preferred raw materials or mobility patterns from these data difficult and potentially misleading. Currently a method of determining the source areas of the multiple kinds of chert at the site is not available. However, there is always the potential for new analysis to emerge and be applied to the 48PA2874 dataset.

Table A.2. Source Material at 48PA2874

Material Type	Count	Percent
Chert	1668	67.5
Chalcedony	249	10.1
Mudstone	214	8.7
Quartzite	206	8.3
Obsidian	42	1.7
Petrified Wood	41	1.7
Morrison For. Quartzite	27	1.1
Irish Rock Chert	6	.2
Volcanic/Basalt	5	.2
Madison For. Chert	3	.1
Phosphoria	2	.1
Dollar Mountain Chert	1	.05
Porecelanite	1	.05
Unspecified	6	.2
Total	2471	100

Table A.3. Source Material in Concentrations

Material	Con 1	Con 2	Con 3	Con 4	Con 5	Con 6
Chert	66	71	74	63.9	57	48
Chalcedony	12	11	10.7	7.8	10.3	18.2
Mudstone	5.6	5	3.5	17	24.3	10.4
Quartzite	11.5	9	5	6	5.6	15
Obsidian	1.7	0.2	3	3	0	4.2
Pet. Wood*	0.54	3	2	0	2.8	0
Mor. Qt.*	2.3	0.2	0	1.9	0	2.1
IR Chert*	0.36	0.2	0.6	0	0	0
Volcanic	0	0.1	0	0.2	0	0
Mad Chert*	0	0	0.6	0	0	2.1
Phosphoria	0	0.1	0	0	0	0
DM Chert*	0	0	0	0	0	0
Porecelanite	0	0.1	0	0	0	0
Unspecified	0	0.1	0.6	0.2	0	0
	100	100	100	100	100	100

Obsidian Hydration Analysis

Obsidian comprises slightly less than 2% of the total assemblage at 48PA2874. Bohn's conducted obsidian source analysis on a total of 12 artifacts from the site, four from Concentration 1, four from Concentration 3, two from Concentration 4 and two artifacts outside the concentrations (Bohn 2007:98). Analysis showed obsidian originated from three areas; Obsidian Cliff located 140 km (87 miles) northwest, Teton Pass 142 km (88 miles) west/southwest, and Park Point, the closest source area found at 87 km (54 miles) northwest (Bohn 2007:47). Obsidian in Concentration 1 sourced to Obsidian Cliff (n=3) and Teton Pass (n=1). Concentration 3 contained three artifacts from Obsidian Cliff and one from Teton Pass. Concentration 4 had one artifact from Obsidian Cliff and one from Park Point (Bohn 2007:98, 47). The two artifacts analyzed outside the concentrations were sourced to Obsidian Cliff. The vast majority of the obsidian artifacts (75%) sourced to Obsidian Cliff, Wyoming. Although Obsidian Cliff is not the closest location to the project area, prehistorically it was a highly utilized obsidian source area. Projectile points found in concentrations with sourced obsidian indicate all were occupied all various times in the past. Therefore linking specific time periods with a particular obsidian source area is not possible. However the study shows occupants of 48PA2874 obtained obsidian from multiple source areas from great distances. Although it appears Obsidian Cliff may have been a preferred source, artifacts undergoing this analysis represent a small portion of the obsidian located at the site. Additional testing would aid in interpreting these data.

Table A.4. Obsidian Source Areas

Source Area	Artifact Count	Percent
Obsidian Cliff	9	75%
Teton Pass	2	17%
Park Point	1	8%
Total	12	100%

Tools and Source Material

Of the 26 projectile points found at the site, 54% were manufactured from chert that could not be identified as local or non-local material (Table A.5). Five projectile points, 19% were manufactured from locally available raw material and six projectile points, 27% from non-local stone. Paleoindian points (n=2) were manufactured from porecelanite, an exotic toolstone available in the Big Horn Basin and from a high quality chert, which has a high likelihood of being non-local. One of the two early Early Archaic points found at the site is Dollar Mountain chert- the only point composed of this type of locally available material. The other Early Archaic projectile point is manufactured from chert from an unknown source. The Middle Archaic points are composed of unidentifiable chert (n=3) and Morrison Formation quartzite (n=1). Of the temporally diagnostic projectile points, the Late Archaic has the most diverse sources including chert (n=1), quartzite (n=2), mudstone (n=1), and chalcedony (n=2). However, Late Archaic projectile points are also the most numerous of the temporally identifiable points (n=6). The source material of projectile points that can only be identified to the general Archaic period include Morrison Quartzite (n=1), obsidian (n=1), and chert (n=2). Projectile points too fragmented to be associated with any time period were composed of mudstone (n=1), obsidian (n=1), and chert (n=4).

Table A.5. Source Material of Projectile Points

Material Type	Paleo-Indian	Early Archaic	Middle Archaic	Late Archaic	General Archaic	Late Prehistoric	Not Known	Total
LOCAL SOURCE MATERIAL								
Chalcedony	-	-	-	2	-	-	-	2
Dollar Mt*	-	1	-	-	-	-	-	1
Mudstone	-	-	-	1	-	-	1	2
Total	**-**	**1**	**-**	**3**	**-**	**-**	**1**	**5**
NON-LOCAL SOURCE MATERIAL								
Morr. Qt.**	-	-	1	-	1	-	-	2
Quartzite	-	-	-	2	-	-	-	2
Obsidian	-	-	-	-	1	-	1	2
Porecelanite	1	-	-	-	-	-	-	1
Total	**1**	**-**	**1**	**2**	**2**	**-**	**1**	**7**
UNKNOWN SOURCE LOCATION								
Chert	1	1	3	1	2	2	4	14
Total	**1**	**1**	**3**	**1**	**2**	**2**	**4**	**14**
Total All	2	2	4	6	4	2	6	26
Percent All	8%	8%	15%	23%	15%	8%	23%	100%

*Dollar Mountain Chert
** Morrison Formation Quartzite

Of the other formal tools (defined as Stage 3 and higher bifaces, scrapers, and awls) 73% were composed of unidentifiable source material, 21% were local material, and 6% were non-local. Worked flakes were more frequently composed of local material (31% local) then the entire site assemblage (21% local), the projectile points assemblage (19% local), and all other formal tools (21% local) (Table A.6a,b). Although formal tools have the lowest percentage of non-local material, it also has the highest percent of unidentifiable sources that could skew the data in either direction.

Table A.6a. Source Material of Formal Tools: Bifaces, Scrapers, and Awls

Material Type	Count	Percent
Chert	23	69.7
Chalcedony	1	3
Mudstone	4	12.1
Petrified Wood	1	3
Morrison For. Quartzite	1	3
Madison For. Chert	1	3
Unspecified	1	3
Total	33	100

Table A.6b. Source Material of Expedient Tools: Worked Flakes

Material Type	Count	Percent
Chert	7	43.8
Chalcedony	1	6.3
Mudstone	3	18.8
Obsidian	1	6.3
Quartzite	3	18.8
Volcanic	1	6.3
Total	16	100

Temporally Diagnostic Projectile Points

The number of chronologically diagnostic point types can not be directly correlated with the intensity of occupation during the associated time frame, however it can be noted Middle Archaic and Late Prehistoric projectile points are the most heavily represented cultural periods at 48PA2874. It is likely the points identified to-date do not represent all the projectile points present at the site currently or prehistorically. Survey certainly did not encounter every artifact and it is likely some projectile points have been collected looters. Tools can be reused by later peoples, thereby seemly reducing the number of projectile points from earlier time periods. Regardless of the problems linking the chronologically diagnostic points with the degree of site use overtime, it can safely be stated the site was occupied intermittently for the last 9, 000 years.

Summary

The ultimate goal of examining the artifact assemblage at 48PA2874 is to contribute to the growing understanding of past human use of the Upper Greybull region. What information can be inferred from the cultural material found in the study area? Chronologically diagnostic projectile points indicate humans hunted in the area from 9,000 BP through the Late Prehistoric. The absence of ground stone may indicate game, rather than vegetal material was the primary resource used at the site.

The overall artifact assemblage within the project area had very few artifacts with cortex. If early stage reduction of source material was taking place a large number of cores or nodules would be expected. However, only .2% of the entire lithic assemblage consisted of cores or nodules. Nor is the area a source of tool stone as no outcrops or deposits of workable material is present. Clearly, initial production of stone tools was not the primary activity occurring at the site.

Source material of tool stone shows prehistoric people had a wide geographic range, from the Big Horn Mountains to the east, to modern day Yellowstone National Park to the north, and Teton Pass to the west. While these locations and human mobility can not be associated with particular time periods, the presence of these material types show not all resources were locally obtained.

Artifacts and features indicate more than brief instances of opportunistic hunting occurred at 48PA2874. The presence of clusters of heat impacted artifacts surrounded by lithic debris and tools suggest hearths and activity areas are associated with a longer-term presence such as a campsite.

APPENDIX B

APPENDIX B

Results of Statistical Analysis

Test Excavation Artifact and Site Surface Assemblage

Table B1. U27 Artifacts and Site Surface Assemblage
All Artifacts from U27-16 and U27-17 Combined for Analysis

	Location	Count	Mean	Std. Deviation	*t*- test Sig. (2-tailed)
Length	U27	63	13.721	11.171	**.030***
	Surface	2705	16.580	10.342	
Elongation	U27	63	.67997	.15963	**.010***
	Surface	2705	.7302	.1538	
Flatness	U27	63	.2455	.1244	.397
	Surface	2705	.2610	.1441	
Blockiness	U27	63	.0369	.0212	**.011***
	Surface	2705	.0453	.0261	
Weight	U27	63	8.556	7.4559	**.020***
	Surface	2705	10.539	6.6639	

**Significant at the alpha 0.05 level*

Table B2. T26 Artifacts by Depth and Site Surface Assemblage
Artifacts from T26-6 and T26-7 Artifacts Combined by Depth for Analysis

T26: 0-5 cmbs and Site Surface Assemblage

	CMBS	Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	0-5	55	8.655	4.0157	**.000***
	Surface	2705	16.580	10.3421	
Elongation	0-5	55	.7441	.1543	.511
	Surface	2705	.7302	.1537	
Flatness	0-5	55	.1854	.0829	**.008***
	Surface	2705	.2610	.1441	
Blockiness	0-5	55	.0347	.0179	**.003***
	Surface	2705	.0453	.02610	
Weight	0-5	55	5.3903	2.6432	**.000***
	Surface	2705	10.5396	6.6639	

T26: 5-10 cmbs and Site Surface Assemblage

	CMBS	N	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	5-10	85	8.746	4.5183	**.000***
	Surface	2705	16.580	10.3421	
Elongation	5-10	85	.6929	.1606	**.028***
	Surface	2705	.7302	.1537	
Flatness	5-10	85	.1964	.0892	**.000***
	Surface	2705	.2610	.1441	
Blockiness	5-10	85	.0318	.0203	**.000***
	Surface	2705	.0453	.0260	
Weight	5-10	85	5.2306	2.6216	**.000***
	Surface	2705	10.5396	6.6639	

T26: 10-15 cmbs and Site Surface Assemblage

	CMBS	N	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	10-15	128	10.170	7.7336	**.000***
	Surface	2705	16.580	10.3421	
Elongation	10-15	128	.7371	.1402	.621
	Surface	2705	.7302	.1538	
Flatness	10-15	128	.2343	.1322	**.040***
	Surface	2705	.2610	.1441	
Blockiness	10-15	128	.0411	.0265	.076
	Surface	2705	.0453	.0261	
Weight	10-15	128	6.6059	6.3926	**.000***
	Surface		10.5396	6.6639	

T26: 15-20 cmbs and Site Surface Assemblage

	CMBS	N	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	15-20	49	10.833	6.3622	**.000***
	Surface	2705	16.580	10.3734	
Elongation	15-20	49	.7142	.1556	.470
	Surface	2705	.7302	.1538	
Flatness	15-20	49	.2312	.1259	.108
	Surface	2705	.2610	.1441	
Blockiness	15-20	49	.0361	.0194	**.002***
	Surface	2705	.0453	.0261	
Weight	15-20	49	6.6312	3.5190	**.000***
	Surface	2705	10.5396	6.6639	

T26: 20-25 cmbs and Site Surface Assemblage

	CMBS	N	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	20-25	34	11.085	4.6827	**.002***
	Surface	2705	16.580	10.3421	
Elongation	20-25	34	.6978	.1932	.225
	Surface	2705	.7301	.1537	
Flatness	20-25	34	.2100	.0817	**.040***
	Surface	2705	.2609	.1441	
Blockiness	20-25	34	.0330	.0143	**.000***
	Surface	2705	.0453	.0261	
Weight	20-25	34	6.6990	2.844	**.000***
	Surface	2705	10.5396	6.6639	

T26: 25-30 cmbs and Site Surface Assemblage

	CMBS	Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	25-30	31	10.248	6.7105	**.001***
	Surface	2705	16.580	10.3421	
Elongation	25-30	30	.7345	.1664	.877
	Surface	2705	.7301	.1537	
Flatness	25-30	31	.2202	.1333	.117
	Site	2705	.2609	.1441	
Blockiness	25-30	31	.0403	.0312	.289
	Surface	2705	.0453	.0260	
Weight	25-30	31	6.6139	4.6366	**.001***
	Surface	2705	10.5396	6.6639	

**Significant at the alpha 0.05 level*

Pocket Gopher and Site Surface Artifacts

Table B3. *t*-test of Artifact Length in Burrows, Site Surface, and Buffer Areas

Area	T	df	Sig. (2-tailed)
Site	-1.063	2583	.288
0 – 2 m	-1.502	186	.135
2 – 4 m	-1.364	243	.642
4 – 6 m	-.373	337	.710
6 – 8 m	-1.890	322	.060
8 - 10m	-.445	319	.657
0 – 4 m	-1.601	317	.110
6 - 10 m	-1.281	547	.201

Table B4. *t*-test of Elongation and Flatness of Artifacts in Burrows, Site Surface, and Buffer Areas

	Elongation			Flatness		
Location	**T**	**Df**	**Sig. (2-tailed)**	**T**	**Df**	**Sig. (2-tailed)**
Site Surface	1.204	2818	.229	-.479	2818	.632
0 – 2 m	-1.502	186	.135	-1.305	186	.194
2 – 4 m	.428	243	.669	-.968	243	.334
4 – 6 m	1.35	337	.178	-.559	337	.576
6 – 8 m	1.485	322	.139	-.542	322	.588
8 – 10 m	1.598	319	.111	-.538	319	.591
0 – 4 m	.666	317	.506	-1.201	317	.231
6 - 10 m	1.564	547	.118	-.597	547	.551

Table B5. *t*-test of Blockiness/Sphericity and Weight of Artifacts in Burrows, Site Surface, and Buffer Areas

	Blockiness/Sphericity			Weight		
Location	**T**	**Df**	**Sig. (2-tailed)**	**T**	**Df**	**Sig. (2-tailed)**
Site Surface	.051	2817	.959	-1.687	126.334	.094
0 – 2 m	-1.226	186	.222	-1.312	186	.191
2 – 4 m	-1.089	243	.227	-1.707	243	.089
4 – 6 m	.308	337	.576	-.442	337	.659
6 – 8 m	-.100	322	.920	-1.943	322	.053
8 - 10m	.265	319	.791	-.270	319	.787
0 – 4 m	-1.183	317	.283	-1.650	317	.238
6 - 10 m	.120	547	.904	-1.174	547	.241

Pocket Gopher and Excavation Artifacts

Table B6. Statistical Analysis of Pocket Gopher and U27 Artifacts

		Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	Gopher	114	14.9	8.53	.428
	U27	63	13.7	11.17	
Elongation	Gopher	114	.7486	.1606	.007*
	U27	63	.6799	.1596	
Flatness	Gopher	114	.2538	.1490	.707
	U27	63	.2454	.1243	
Blockiness	Gopher	114	.0446	.0225	.027*
	U27	63	.0368	.0212	
Weight	Gopher	114	9.49	5.3745	.333
	U27	63	8.55	7.4559	

**Significant at the alpha 0.05 level*

Table B7. Statistical Analysis of Pocket Gopher and T26 Artifacts

Pocket Gopher Artifacts and T26: 0 - 5 cmbs

		Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	Gopher	114	14.92	8.536	.000*
	0 -5	55	8.65	4.015	
Elongation	Gopher	114	.7486	.1607	.863
	0 -5	55	.7441	.1544	
Flatness	Gopher	114	.2538	.1491	.000*
	0 -5	55	.1854	.0829	
Blockiness	Gopher	114	.0446	.0225	.005*
	0 -5	55	.0347	.0179	
Weight	Gopher	114	9.4997	5.3726	.000*
	0 -5	55	5.3903	2.6433	

Pocket Gopher Artifacts and T26: 5 – 10 cmbs

		Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	Gopher	114	14.92	8.536	.000*
	5 – 10	85	8.746	4.5183	
Elongation	Gopher	114	.7486	.1607	.016*
	5 – 10	85	.6929	.1605	
Flatness	Gopher	114	.2538	.1491	.001*
	5 – 10	85	.1963	.0829	
Blockiness	Gopher	114	.0446	.0225	.000*
	5 – 10	85	.0319	.0203	
Weight	Gopher	114	9.4997	5.3726	.000*
	5 – 10	85	5.2305	2.6215	

Pocket Gopher Artifacts and T26: 10 – 15 cmbs

		Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	Gopher	114	14.92	8.536	.000*
	10 -15	128	10.17	7.734	
Elongation	Gopher	114	.7486	.1607	.551
	10 -15	128	.7370	.1401	
Flatness	Gopher	114	.2538	.1490	.281
	10 -15	128	.2342	.1322	
Blockiness	Gopher	114	.0446	.0225	.273
	10 -15	128	.0411	.0265	
Weight	Gopher	114	9.4997	5.3726	.000*
	10 -15	128	6.606	6.3925	

Pocket Gopher Artifacts and T26: 15 - 20 cmbs

		Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	Gopher	114	14.92	8.536	.003*
	15 – 20	49	10.833	6.3622	
Elongation	Gopher	114	.7486	.1607	.207
	15 – 20	49	.7141	.1555	
Flatness	Gopher	114	.2538	.1490	.355
	15 – 20	49	.2312	.1259	
Blockiness	Gopher	114	.0446	.0225	.023*
	15 – 20	49	.0361	.0194	
Weight	Gopher	114	9.4997	5.3726	.000*
	15 – 20	49	6.6313	3.5190	

Pocket Gopher Artifacts and T26: 20 - 25 cmbs

		Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	Gopher	114	14.92	8.536	.014*
	20 – 25	34	11.085	4.683	
Elongation	Gopher	114	.7486	.1607	.126
	20 – 25	34	.6978	.1932	
Flatness	Gopher	114	.2538	.1490	.104
	20 – 25	34	.2100	.0817	
Blockiness	Gopher	114	.0446	.0225	.005*
	20 – 25	34	.0330	.0142	
Weight	Gopher	114	9.4997	5.3726	.000*
	20 – 25	34	6.6990	2.8437	

Pocket Gopher Artifacts and T26: 25 - 30 cmbs

		Count	Mean	Std. Deviation	t-test Sig. (2-tailed)
Length	Gopher	114	14.92	8.536	.006*
	25 -30	31	10.248	6.7105	
Elongation	Gopher	114	.7486	.1607	.673
	25 – 30	31	.7346	.1665	
Flatness	Gopher	114	.2538	.1490	.258
	25 – 30	31	.2203	.1333	
Blockiness	Gopher	114	.0446	.0225	.476
	25 – 30	31	.0403	.03125	
Weight	Gopher	114	9.4997	5.3726	.007*
	25 – 30	31	6.6140	4.6367	

**Significant at the alpha 0.05 level*

T26: Excavation Artifact

Table B8. All T26 Artifacts: T26-6, T26-7 Artifacts Combined and Compared by Depth

T26 0-5 and 5-10 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	0-5	55	8.655	4.0157	.5415
	5-10	85	8.746	4.5183	.4901
Elongation	0-5	55	.74410848	.154365927	.020814697
	5-10	85	.69285027	.160577062	.017417028
Flatness	0-5	55	.18539854	.082866193	.011173675
	5-10	85	.19636985	.089160709	.009670837
Blockiness	0-5	55	.03472991	.017980753	.002424524
	5-10	85	.03183675	.020267262	.002198293
Weight	0-5	55	5.39030303	2.643227799	.356412764
	5-10	85	5.23058824	2.621594348	.284351831

T26 0-5 and 5-10 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.098	.755	-.122	138	.903	-.0913	.7491	-1.5725	1.3898
	Equal variances not assumed			-.125	124.84	.901	-.0913	.7303	-1.5368	1.3541
Elongation	Equal variances assumed	.100	.752	1.873	138	.063	.0512582	.0273724	-.00286533	.1053875
	Equal variances not assumed			1.889	118.68	.061	.0512582	.0271404	-.00248402	.10500045
Flatness	Equal variances assumed	.129	.720	-.731	138	.466	-.0109730	.0150124	-.04065553	.0187195
	Equal variances not assumed			-.742	121.40	.459	-.0109713	.0147775	-.04022633	.0182376
Blockiness	Equal variances assumed	.001	.973	.862	138	.390	.0028931	.0033579	-.00374665	.0093291
	Equal variances not assumed			.884	124.98	.378	.0028931	.0032727	-.00358407	.0037030
Weight	Equal variances assumed	.058	.811	.351	138	.726	.1597147	.4551371	-.74022957	1.059659
	Equal variances not assumed			.350	114.73	.727	.1597147	.4559451	-.74344685	1.062876

T26 0-5 and 10-15 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	0-5	55	8.655	4.0157	.5415
	10-15	128	10.170	7.7336	.6836
Elongation	0-5	55	.74410848	.154365927	.020814697
	10-15	128	.73705377	.140165963	.012389038
Flatness	0-5	55	.18539854	.082866193	.011173675
	10-15	128	.23425873	.132208236	.011685667
Blockiness	0-5	55	.03472991	.017980753	.002424524
	10-15	128	.04112461	.026521370	.002344180
Weight	0-5	55	5.39030303	2.643227799	.356412764
	10-15	128	6.60598958	6.392562435	.565028031

T26 0-5 and 10-15 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	1.626	.204	-1.37	181	.171	-1.5158	1.1027	-3.6915	.6600
	Equal variances not assumed			-1.73	174.653	.084	-1.5158	.8720	-3.2369	.2053
Elongation	Equal variances assumed	1.815	.180	.303	181	.762	.007054711	.023305198	-.038904	.053039526
	Equal variances not assumed			.291	94.021	.772	.007054711	.024222714	-.041035	.055149337
Flatness	Equal variances assumed	6.738	.010	-2.53	181	.012	-.04880194	.019288733	-.086913	-.01080496
	Equal variances not assumed			-3.02	156.910	.003	-.04880194	.016168050	-.080753	-.01692505
Blockiness	Equal variances assumed	.440	.508	-1.63	181	.104	-.00639702	.003916171	-.014122	.001332519
	Equal variances not assumed			-1.89	147.386	.060	-.00639402	.003372462	-.013598	.000269925
Weight	Equal variances assumed	2.026	.156	-1.36	181	.176	-1.2156553	.894159624	-2.98001	.548630805
	Equal variances not assumed			-1.82	180.838	.070	-1.2156553	.668046955	-2.53386	.102482960

T26 0-5 and 15-20 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	0-5	55	8.655	4.0157	.5415
	15-20	49	10.833	6.3622	.9089
Elongation	0-5	55	.74410848	.154365927	.020814697
	15-20	49	.71416473	.155585368	.022226481
Flatness	0-5	55	.18539854	.082866193	.011173675
	15-20	49	.23122887	.125921529	.017988790
Blockiness	0-5	55	.03472991	.017980753	.002424524
	15-20	49	.03613547	.019361331	.002765904
Weight	0-5	55	5.39030303	2.643227799	.356412764
	15-20	49	6.63129252	3.519031644	.502718806

T26 0-5 and 15-20 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	3.030	.085	-2.11	102	.037	-2.1781	1.0318	-4.2246	-.1316
	Equal variances not assumed			-2.09	79.246	.043	-2.1781	1.0580	-4.2838	-.0724
Elongation	Equal variances assumed	.000	.985	.984	102	.328	.029943753	.030437121	-.030132	.090315639
	Equal variances not assumed			.983	100.441	.328	.029943753	.030451077	-.030665	.090354572
Flatness	Equal variances assumed	11.027	.001	-2.25	102	.029	-.04583037	.020693907	-.086804	-.00474070
	Equal variances not assumed			-2.14	81.412	.033	-.04583037	.021176581	-.087989	-.00368815
Blockiness	Equal variances assumed	.270	.605	-.384	102	.702	-.00140567	.003662328	-.008676	.005858643
	Equal variances not assumed			-.382	98.441	.703	-.00140567	.003678117	-.008761	.005893128
Weight	Equal variances assumed	2.600	.110	-2.07	102	.043	-1.2409887	.60631246	-2.44337	-.03835837
	Equal variances not assumed			-2.04	88.505	.047	-1.2409887	.6162436	-2.46586	-.01643187

T26 0-5 and 20-25 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	0-5	55	8.655	4.0157	.5415
	20-25	34	11.085	4.6827	.8031
Elongation	0-5	55	.74410848	.154365927	.020814697
	20-25	34	.69785464	.193225705	.033137935
Flatness	0-5	55	.18539854	.082866193	.011173675
	20-25	34	.21006984	.081773891	.014024107
Blockiness	0-5	55	.03472991	.017980753	.002424524
	20-25	34	.03303606	.014267561	.002446866
Weight	0-5	55	5.39030303	2.643227799	.356412764
	20-25	34	6.69901961	2.843712247	.487692627

T26 0-5 and 20-25
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	1.413	.238	-2.603	87	.011	-2.4307	.9339	-4.2871	-.5744
	Equal variances not assumed			-2.510	61.995	.015	-2.4307	.9686	-4.3669	-.4946
Elongation	Equal variances assumed	2.442	.122	1.246	87	.216	.046253845	.037120671	-.02727508	.120035198
	Equal variances not assumed			1.182	58.602	.242	.046253845	.039132779	-.03206199	.124569489
Flatness	Equal variances assumed	.126	.723	-1.372	87	.174	-.02467306	.017988034	-.06042470	.011081859
	Equal variances not assumed			-1.376	70.768	.173	-.02467106	.017931162	-.06042760	.011084449
Blockiness	Equal variances assumed	1.929	.168	.466	87	.643	.001693847	.003636709	-.00553505	.008922199
	Equal variances not assumed			.492	81.563	.624	.001693847	.003444630	-.00515968	.008546862
Weight	Equal variances assumed	.834	.364	-2.205	87	.030	-1.3087178	.593614945	-2.4859559	-.12884296
	Equal variances not assumed			-2.167	66.135	.034	-1.3087678	.604048141	-2.5146189	-.10274166

T26 0-5 and 25-30 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	0-5	55	8.655	4.0157	.5415
	25-30	31	10.248	6.7105	1.2052
Elongation	0-5	55	.74410848	.154365927	.020814697
	25-30	30	.73457752	.166460937	.030391470
Flatness	0-5	55	.18539854	.082866193	.011173675
	25-30	31	.22025151	.133337628	.023948145
Blockiness	0-5	55	.03472991	.017980753	.002424524
	25-30	31	.04031145	.031251576	.005612949
Weight	0-5	55	5.39030303	2.643227799	.356412764
	25-30	31	6.61397849	4.636671653	.832770813

T26 0-5 - 25-30 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	9.979	.002	-1.380	84	.171	-1.5938	1.1550	-3.8907	.7031
	Equal variances not assumed			-1.206	42.374	.234	-1.5938	1.3213	-4.2596	1.0719
Elongation	Equal variances assumed	.421	.518	.265	83	.792	.009530965	.036019310	-.06210994	.081171925
	Equal variances not assumed			.259	55.973	.797	.009530965	.036836030	-.06426158	.083323189
Flatness	Equal variances assumed	3.949	.050	-1.496	84	.138	-.03482970	.023300953	-.08118971	.011483531
	Equal variances not assumed			-1.319	43.342	.194	-.03482970	.026426590	-.08813599	.018429159
Blockiness	Equal variances assumed	1.880	.174	-1.053	84	.295	-.00558537	.005298798	-.01611878	.004955704
	Equal variances not assumed			-.913	41.438	.367	-.00558137	.006114206	-.01792464	.006762390
Weight	Equal variances assumed	13.387	.000	-1.562	84	.122	-1.2275464	.783473005	-2.7897456	.334346528
	Equal variances not assumed			-1.351	41.228	.184	-1.2236464	.905835131	-3.0523044	.605388116

T26 5-10 and 10-15 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	5-10	85	8.746	4.5183	.4901
	10-15	128	10.170	7.7336	.6836
Elongation	5-10	85	.69285027	.160577062	.017417028
	10-15	128	.73705377	.140165963	.012389038
Flatness	5-10	85	.19636985	.089160709	.009670837
	10-15	128	.23425873	.132208236	.011685667
Blockiness	5-10	85	.03183675	.020267262	.002198293
	10-15	128	.04112461	.026521370	.002344180
Weight	5-10	85	5.23058824	2.621594348	.284351831
	10-15	128	6.60598958	6.392562435	.565028031

T26 5-10 and 10-15 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	1.713	.192	-1.533	211	.127	-1.4244	.9294	-3.2566	.4077
	Equal variances not assumed			-1.694	208.019	.092	-1.4244	.8411	-3.0826	.2337
Elongation	Equal variances assumed	3.653	.057	-2.126	211	.035	-.04420300	.020795806	-.08519762	-.00209339
	Equal variances not assumed			-2.068	162.921	.040	-.04420500	.021373842	-.08640898	-.00199833
Flatness	Equal variances assumed	7.454	.007	-2.315	211	.022	-.03788885	.016368277	-.07015189	-.00562280
	Equal variances not assumed			-2.498	210.938	.013	-.03788885	.015168385	-.06779928	-.00798742
Blockiness	Equal variances assumed	.622	.431	-2.740	211	.007	-.00927858	.003389639	-.01596974	-.00260962
	Equal variances not assumed			-2.890	206.794	.004	-.00928788	.003213670	-.01562614	-.00295102
Weight	Equal variances assumed	3.502	.063	-1.880	211	.061	-1.3751348	.731500586	-2.8136981	.066584285
	Equal variances not assumed			-2.174	181.841	.031	-1.3750148	.632544575	-2.6234701	-.12733095

T26 5-10 and 15 -20 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	5-10	85	8.746	4.5183	.4901
	15-20	49	10.833	6.3622	.9089
Elongation	5-10	85	.69285027	.160577062	.017417028
	15-20	49	.71416473	.155585368	.022226481
Flatness	5-10	85	.19636985	.089160709	.009670837
	15-20	49	.23122887	.125921529	.017988790
Blockiness	5-10	85	.03183675	.020267262	.002198293
	15-20	49	.03613547	.019361331	.002765904
Weight	5-10	85	5.23058824	2.621594348	.284351831
	15-20	49	6.63129252	3.519031644	.502718806

T26 5-10 and 15 -20 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	2.667	.105	-2.210	132	.029	-2.0868	.9442	-3.9545	-.2190
	Equal variances not assumed			-2.021	76.284	.047	-2.0868	1.0326	-4.1432	-.0303
Elongation	Equal variances assumed	.103	.749	-.748	132	.456	-.02131458	.028480057	-.07765826	.035021910
	Equal variances not assumed			-.755	102.881	.452	-.02131458	.028237729	-.07731812	.034689187
Flatness	Equal variances assumed	10.507	.002	-1.868	132	.064	-.03485927	.018661821	-.07177354	.002055899
	Equal variances not assumed			-1.707	76.122	.092	-.03485027	.020423556	-.07553503	.005816958
Blockiness	Equal variances assumed	.217	.642	-1.202	132	.232	-.00429873	.003577063	-.01137457	.002777060
	Equal variances not assumed			-1.217	104.066	.226	-.00429873	.003533089	-.01130420	.002707473
Weight	Equal variances assumed	3.995	.048	-2.621	132	.010	-1.4007282	.534405008	-2.457029	-.34358354
	Equal variances not assumed			-2.425	79.006	.018	-1.4000482	.577565721	-2.5503864	-.25108800

T26 5-10 and 20 - 25 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	5-10	85	8.746	4.5183	.4901
	20-25	34	11.085	4.6827	.8031
Elongation	5-10	85	.69285027	.160577062	.017417028
	20-25	34	.69785464	.193225705	.033137935
Flatness	5-10	85	.19636985	.089160709	.009670837
	20-25	34	.21006984	.081773891	.014024107
Blockiness	5-10	85	.03183675	.020267262	.002198293
	20-25	34	.03303606	.014267561	.002446866
Weight	5-10	85	5.23058824	2.621594348	.284351831
	20-25	34	6.69901961	2.843712247	.487692627

T26 5-10 and 20 -25 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.736	.393	-2.525	117	.013	-2.3394	.9264	-4.1741	-.5048
	Equal variances not assumed			-2.487	58.944	.016	-2.3394	.9408	-4.2220	-.4568
Elongation	Equal variances assumed	1.991	.161	-.145	117	.885	-.00500436	.034581628	-.07349168	.063482736
	Equal variances not assumed			-.134	52.186	.894	-.00500436	.037436287	-.08011997	.070110665
Flatness	Equal variances assumed	.001	.972	-.775	117	.440	-.01369996	.017682573	-.04871405	.021319413
	Equal variances not assumed			-.804	65.985	.424	-.01369996	.017035277	-.04771164	.020312172
Blockiness	Equal variances assumed	1.226	.271	-.315	117	.753	-.00119930	.003808851	-.00874540	.006343920
	Equal variances not assumed			-.365	85.809	.716	-.00119930	.003289323	-.00773876	.005339857
Weight	Equal variances assumed	1.356	.247	-2.694	117	.008	-1.4684373	.545063712	-2.5479013	-.38896122
	Equal variances not assumed			-2.601	56.677	.012	-1.4684133	.564535262	-2.5990387	-.33782959

T26 5-10 and 25-30 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	5-10	85	8.746	4.5183	.4901
	25-30	31	10.248	6.7105	1.2052
Elongation	5-10	85	.69285027	.160577062	.017417028
	25-30	30	.73457752	.166460937	.030391470
Flatness	5-10	85	.19636985	.089160709	.009670837
	25-30	31	.22025151	.133337628	.023948145
Blockiness	5-10	85	.03183675	.020267262	.002198293
	25-30	31	.04031145	.031251576	.005612949
Weight	5-10	85	5.23058824	2.621594348	.284351831
	25-30	31	6.61397849	4.636671653	.832770813

T26 5-10 and 25-30
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	8.557	.004	-1.381	114	.170	-1.5025	1.0881	-3.6580	.6530
	Equal variances not assumed			-1.155	40.347	.255	-1.5025	1.3011	-4.1314	1.1263
Elongation	Equal variances assumed	.168	.682	-1.212	113	.228	-.04172246	.034425624	-.10990616	.026476124
	Equal variances not assumed			-1.191	49.340	.239	-.04177246	.035028478	-.11210750	.028652858
Flatness	Equal variances assumed	3.602	.060	-1.109	114	.270	-.02388660	.021536865	-.06654025	.018782704
	Equal variances not assumed			-.925	40.200	.361	-.02388660	.025827093	-.07607257	.028308736
Blockiness	Equal variances assumed	2.050	.155	-1.707	114	.090	-.00847494	.004963747	-.01830739	.001358451
	Equal variances not assumed			-1.406	39.577	.168	-.00847464	.006028075	-.02066190	.003712562
Weight	Equal variances assumed	17.496	.000	-2.014	114	.046	-1.3833259	.687021648	-2.7437853	-.02245666
	Equal variances not assumed			-1.572	37.222	.124	-1.3833259	.879979085	-3.1667578	.399257059

T26 10-15 and 15-20 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	10-15	128	10.170	7.7336	.6836
	15-20	49	10.833	6.3622	.9089
Elongation	10-15	128	.73705377	.140165963	.012389038
	15-20	49	.71416473	.155585368	.022226481
Flatness	10-15	128	.23425873	.132208236	.011685667
	15-20	49	.23122887	.125921529	.017988790
Blockiness	10-15	128	.04112461	.026521370	.002344180
	15-20	49	.03613547	.019361331	.002765904
Weight	10-15	128	6.60598958	6.392562435	.565028031
	15-20	49	6.63129252	3.519031644	.502718806

T26 10-15 and 15-20 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.014	.905	-.534	175	.594	-.6623	1.2402	-3.1101	1.7854
	Equal variances not assumed			-.582	104.964	.562	-.6623	1.1372	-2.9173	1.5926
Elongation	Equal variances assumed	1.589	.209	.943	175	.347	.022889043	.024284488	-.025039126	.070817211
	Equal variances not assumed			.900	79.558	.371	.022889043	.025446114	-.027754662	.073532747
Flatness	Equal variances assumed	.230	.632	.138	175	.890	.003029857	.021925060	-.040241714	.046301429
	Equal variances not assumed			.141	90.938	.888	.003029857	.021451140	-.039580586	.045640301
Blockiness	Equal variances assumed	.999	.319	1.199	175	.232	.004989135	.004160169	-.003221426	.013199696
	Equal variances not assumed			1.376	118.596	.171	.004989135	.003625660	-.002190285	.012168554
Weight	Equal variances assumed	.256	.613	-.026	175	.979	-.025302934	.965801903	-1.931421605	1.880815738
	Equal variances not assumed			-.033	153.368	.973	-.025302934	.756295494	-1.519404381	1.468798514

T26 10-15 and 20 -25
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	10-15	128	10.170	7.7336	.6836
	20-25	34	11.085	4.6827	.8031
Elongation	10-15	128	.73705377	.140165963	.012389038
	20-25	34	.69785464	.193225705	.033137935
Flatness	10-15	128	.23425873	.132208236	.011685667
	20-25	34	.21006984	.081773891	.014024107
Blockiness	10-15	128	.04112461	.026521370	.002344180
	20-25	34	.03303606	.014267561	.002446866
Weight	10-15	128	6.60598958	6.392562435	.565028031
	20-25	34	6.69901961	2.843712247	.487692627

T26 10-15 and 20 -25 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.157	.692	-.658	160	.512	-.9150	1.3912	-3.6625	1.8325
	Equal variances not assumed			-.868	86.359	.388	-.9150	1.0546	-3.0113	1.1814
Elongation	Equal variances assumed	8.230	.005	1.331	160	.185	.039199134	.029447224	-.01896234	.097354502
	Equal variances not assumed			1.108	42.653	.274	.039199134	.035378115	-.03214412	.110562681
Flatness	Equal variances assumed	3.491	.064	1.015	160	.312	.024188888	.023828294	-.02286646	.071247423
	Equal variances not assumed			1.325	84.188	.189	.024188888	.018254599	-.01211102	.060488979
Blockiness	Equal variances assumed	1.820	.179	1.711	160	.089	.008088549	.004727108	-.00124724	.017424121
	Equal variances not assumed			2.387	99.579	.019	.008088549	.003388560	.001365395	.014811702
Weight	Equal variances assumed	.568	.452	-.083	160	.934	-.09303025	1.126725221	-2.3181421	2.132141372
	Equal variances not assumed			-.125	123.316	.901	-.09303025	.746391837	-1.5704280	1.384369231

T26 10-15 and 25-30 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	10-15	128	10.170	7.7336	.6836
	25-30	31	10.248	6.7105	1.2052
Elongation	10-15	128	.73705377	.140165963	.012389038
	25-30	30	.73457752	.166460937	.030391470
Flatness	10-15	128	.23425873	.132208236	.011685667
	25-30	31	.22025151	.133337628	.023948145
Blockiness	10-15	128	.04112461	.026521370	.002344180
	25-30	31	.04031145	.031251576	.005612949
Weight	10-15	128	6.60598958	6.392562435	.565028031
	25-30	31	6.61397849	4.636671653	.832770813

T26 10-15 and 25-30 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Con Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.845	.359	-.052	157	.959	-.0781	1.5111	-3.0628	2.9066
	Equal variances not assumed			-.056	51.154	.955	-.0781	1.3856	-2.8596	2.7034
Elongation	Equal variances assumed	3.149	.078	.084	156	.933	.002476255	.029496486	-.055787786	.060740295
	Equal variances not assumed			.075	39.192	.940	.002476255	.032819654	-.063897367	.068849876
Flatness	Equal variances assumed	.018	.893	.528	157	.598	.014007224	.026508308	-.038351699	.066366148
	Equal variances not assumed			.526	45.379	.602	.014007224	.026647110	-.039650435	.067664884
Blockiness	Equal variances assumed	.549	.460	.148	157	.883	.000813164	.005502489	-.010055293	.011681622
	Equal variances not assumed			.134	41.083	.894	.000813164	.006082793	-.011470535	.013096863
Weight	Equal variances assumed	.492	.484	-.007	157	.995	-.00798811	1.220325892	2.418363388	2.402385566
	Equal variances not assumed			-.008	60.929	.994	-.00798811	1.006361715	-2.02081211	2.004403388

T26 15 – 20 and 20-25 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	15-20	49	10.833	6.3622	.9089
	20-25	34	11.085	4.6827	.8031
Elongation	15-20	49	.71416473	.155585368	.022226481
	20-25	34	.69785464	.193225705	.033137935
Flatness	15-20	49	.23122887	.125921529	.017988790
	20-25	34	.21006984	.081773891	.014024107
Blockiness	15-20	49	.03613547	.019361331	.002765904
	20-25	34	.03303606	.014267561	.002446866
Weight	15-20	49	6.63129252	3.519031644	.502718806
	20-25	34	6.69901961	2.843712247	.487692627

T26 15-20 and 20 -25 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.411	.523	-.197	81	.844	-.2526	1.2807	-2.8008	.844
	Equal variances not assumed			-.208	80.67	.836	-.2526	1.2129	-2.6660	.836
Elongation	Equal variances assumed	2.280	.135	.425	81	.672	.0163100	.038372754	-.06003965	.672
	Equal variances not assumed			.409	60.89	.684	.0163100	.039901619	-.06348085	.684
Flatness	Equal variances assumed	7.044	.010	.861	81	.392	.0211590	.024573313	-.02773414	.392
	Equal variances not assumed			.928	80.71	.356	.0211591	.022809475	-.02422712	.356
Blockiness	Equal variances assumed	.399	.529	.795	81	.429	.0030994	.003898554	-.00465745	.429
	Equal variances not assumed			.839	80.66	.404	.00309	.003692883	-.00424872	.404
Weight	Equal variances assumed	.421	.518	-.093	81	.926	-.06772	.727829206	-1.5158789	.926
	Equal variances not assumed			-.097	79.03	.923	-.067727	.700407236	-1.461842530	.923

T26 15-20 and 25 -30 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	15-20	49	10.833	6.3622	.9089
	25-30	31	10.248	6.7105	1.2052
Elongation	15-20	49	.71416473	.155585368	.022226481
	25-30	30	.73457752	.166460937	.030391470
Flatness	15-20	49	.23122887	.125921529	.017988790
	25-30	31	.22025151	.133337628	.023948145
Blockiness	15-20	49	.03613547	.019361331	.002765904
	25-30	31	.04031145	.031251576	.005612949
Weight	15-20	49	6.63129252	3.519031644	.502718806
	25-30	31	6.61397849	4.636671653	.832770813

T26 15-20 and 25-30
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.970	.328	.392	78	.696	.5843	1.4913	-2.3847	.696
	Equal variances not assumed			.387	61.411	.700	.5843	1.5095	-2.4338	.700
Elongation	Equal variances assumed	.408	.525	-.551	77	.583	-.02041278	.037037824	-.094164	.583
	Equal variances not assumed			-.542	58.250	.590	-.02041278	.037651798	-.095741	.590
Flatness	Equal variances assumed	.256	.614	.371	78	.711	.010977367	.029564073	-.047801	.711
	Equal variances not assumed			.367	61.223	.715	.010977367	.029951798	-.048905	.715
Blockiness	Equal variances assumed	2.257	.137	-.739	78	.462	-.00417591	.005650905	-.015260	.462
	Equal variances not assumed			-.667	44.691	.508	-.00417591	.006257429	-.016781	.508
Weight	Equal variances assumed	3.859	.053	.019	78	.985	.017314022	.914786928	-1.80386	.985
	Equal variances not assumed			.018	51.569	.986	.017314022	.972745303	-1.93507	.986

T26 20-25 and 25-30 cmbs
Group Statistics

	CMBS	N	Mean	Std. Deviation	Std. Error Mean
Length	20-25	34	11.085	4.6827	.8031
	25-30	31	10.248	6.7105	1.2052
Elongation	20-25	34	.69785464	.193225705	.033137935
	25-30	30	.73457752	.166460937	.030391470
Flatness	20-25	34	.21006984	.081773891	.014024107
	25-30	31	.22025151	.133337628	.023948145
Blockiness	20-25	34	.03303606	.014267561	.002446866
	25-30	31	.04031145	.031251576	.005612949
Weight	20-25	34	6.69901961	2.843712247	.487692627
	25-30	31	6.61397849	4.636671653	.832770813

T26 20-25 and 25-30 cmbs
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval Lower	95% Confidence Interval Upper
Length	Equal variances assumed	3.396	.070	.587	63	.559	.8369	1.4250	-2.0108	3.6846
	Equal variances not assumed			.578	53.047	.566	.8369	1.4483	-2.0679	3.7417
Elongation	Equal variances assumed	.631	.430	-.809	62	.422	-.036722	.045388608	-.12745341	.054007656
	Equal variances not assumed			-.817	61.970	.417	-.036722	.044964032	-.12665551	.053159792
Flatness	Equal variances assumed	2.327	.132	-.375	63	.709	-.010181	.027168310	-.06447319	.044109871
	Equal variances not assumed			-.367	48.878	.715	-.010181	.027752283	-.06595478	.045592149
Blockiness	Equal variances assumed	3.410	.070	-1.225	63	.225	-.007275	.005937757	-.01914144	.004590275
	Equal variances not assumed			-1.188	41.135	.242	-.007275	.006123100	-.01964001	.005089232
Weight	Equal variances assumed	6.690	.012	.090	63	.929	.0850411	.944759617	-1.8029333	1.97299260
	Equal variances not assumed			.088	48.880	.930	.0850411	.965065451	-1.8544421	2.0245347

Table B9. Artifacts in T26-6 Compared with Artifacts in T26-7 by Depth

0-5 cmbs T26-6 and T26-7
Group Statistics

	UNIT	N	Mean	Std. Deviation	Std. Error Mean
Length	T26-6	33	8.400	4.2088	.7327
	T26-7	22	9.036	3.7710	.8040
Elongation	T26-6	33	.74833593	.147826302	.025733256
	T26-7	22	.73776730	.167047076	.035614556
Flatness	T26-6	33	.20133811	.082736317	.014402544
	T26-7	22	.16148918	.078920454	.016825897
Blockiness	T26-6	33	.03885951	.019672444	.003424533
	T26-7	22	.02853551	.013215286	.002817508
Weight	T26-6	33	5.30505051	2.922246106	.508697752
	T26-7	22	5.51818182	2.219126271	.473119311

0-5 cmbs T26-6 and T26-7
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Conf Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.072	.789	-.572	53	.570	-.6364	1.1122	-2.8672	1.5945
	Equal variances not assumed			-.585	48.439	.561	-.6364	1.0877	-2.8229	1.5502
Elongation	Equal variances assumed	.906	.346	.247	53	.806	.010568630	.042862201	-.07542058	.096539319
	Equal variances not assumed			.241	41.269	.811	.010568630	.043938560	-.07814515	.099286776
Flatness	Equal variances assumed	.004	.947	1.782	53	.080	.039848937	.022362174	-.00500393	.084701777
	Equal variances not assumed			1.799	46.622	.078	.039848937	.022148230	-.00471797	.084414971
Blockiness	Equal variances assumed	3.829	.056	2.155	53	.036	.010324003	.004789998	.000716483	.019931523
	Equal variances not assumed			2.328	52.988	.024	.010324003	.004434611	.001429251	.019218755
Weight	Equal variances assumed	.110	.741	-.290	53	.773	-.21313113	.733772086	-1.6848976	1.258629110
	Equal variances not assumed			-.307	52.007	.760	-.21313133	.694705179	-1.6071574	1.180892119

5-10 cmbs T26-6 and T26-7
Group Statistics

	UNIT	N	Mean	Std. Deviation	Std. Error Mean
Length	T26-6	70	8.627	4.2997	.5139
	T26-7	15	9.300	5.5653	1.4370
Elongation	T26-6	70	.70138766	.166285729	.019874946
	T26-7	15	.65300913	.127926446	.033030466
Flatness	T26-6	70	.20291257	.087035330	.010402712
	T26-7	15	.16583715	.095656996	.024698530
Blockiness	T26-6	70	.03363284	.020889522	.002496775
	T26-7	15	.02345501	.014915732	.003851225
Weight	T26-6	70	5.19095238	2.496405928	.298377579
	T26-7	15	5.41555556	3.236813705	.835741705

5-10 cmbs T26-6 and T26-7
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Conf Interval	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.965	.329	-.521	83	.604	-.6729	1.2912	-3.2409	1.8952
	Equal variances not assumed			-.441	17.752	.665	-.6729	1.5261	-3.8823	2.5366
Elongation	Equal variances assumed	2.815	.097	1.060	83	.292	.048378528	.045654210	-.04225859	.139182915
	Equal variances not assumed			1.255	25.300	.221	.048378528	.038548997	-.03066903	.127723959
Flatness	Equal variances assumed	.338	.563	1.472	83	.145	.037075414	.025193925	-.01334290	.087185118
	Equal variances not assumed			1.383	19.285	.182	.037075414	.026799884	-.01861409	.093112238
Blockiness	Equal variances assumed	.397	.530	1.788	83	.077	.010177828	.00562516	-.00144356	.021500013
	Equal variances not assumed			2.218	27.264	.035	.010177828	.004589752	.000764706	.019590951
Weight	Equal variances assumed	1.406	.239	-.299	83	.765	-.22460375	.749974301	-1.7162715	1.267065546
	Equal variances not assumed			-.253	17.738	.803	-.22460317	.887408236	-2.0995681	1.641748332

10-15 cmbs T26-6 and T26-7
Group Statistics

	UNIT	N	Mean	Std. Deviation	Std. Error Mean
Length	T26-6	61	10.316	6.9677	.8921
	T26-7	67	10.037	8.4209	1.0288
Elongation	T26-6	61	.75430583	.140973459	.018049802
	T26-7	67	.72134668	.138608277	.016933696
Flatness	T26-6	61	.22760438	.143257448	.018342237
	T26-7	67	.24031718	.122060164	.014912022
Blockiness	T26-6	61	.04132903	.025463180	.003260226
	T26-7	67	.04093849	.027640103	.003376776
Weight	T26-6	61	6.69180328	5.200678929	.665878704
	T26-7	67	6.52786070	7.350690196	.898029737

10-15 cmbs T26-6 and T26-7
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.543	.463	.203	126	.839	.2791	1.3738	-2.4397	2.9978
	Equal variances not assumed			.205	124.895	.838	.2791	1.3617	-2.4159	2.9741
Elongation	Equal variances assumed	.007	.935	1.333	126	.185	.032959147	.024729879	-.0180557	.081898851
	Equal variances not assumed			1.332	124.453	.185	.032959147	.024749655	-.0160595	.081943890
Flatness	Equal variances assumed	.395	.531	-.542	126	.589	-.01271200	.023462397	-.0591195	.033718595
	Equal variances not assumed			-.538	118.474	.592	-.01271800	.023639079	-.0595671	.034097071
Blockiness	Equal variances assumed	.000	.998	.083	126	.934	.000390539	.004711979	-.0089330	.009715407
	Equal variances not assumed			.083	125.980	.934	.000390539	.004693793	-.0088983	.009679431
Weight	Equal variances assumed	.207	.650	.144	126	.885	.163942582	1.135686131	-2.083565	2.411432049
	Equal variances not assumed			.147	118.967	.884	.163942582	1.117967735	-2.049711	2.377636676

15-20 cmbs T26-6 and T26-7
Group Statistics

	UNIT	N	Mean	Std. Deviation	Std. Error Mean
Length	T26-6	30	10.567	6.5662	1.1988
	T26-7	19	11.253	6.1786	1.4175
Elongation	T26-6	30	.75519268	.150014231	.027388726
	T26-7	19	.64938376	.145118574	.033292484
Flatness	T26-6	30	.22579348	.128649531	.023488083
	T26-7	19	.23981108	.124463967	.028553992
Blockiness	T26-6	30	.03989961	.022289600	.004069506
	T26-7	19	.03019211	.011759544	.002697824
Weight	T26-6	30	6.62888889	3.641299222	.664807241
	T26-7	19	6.63508772	3.414827394	.783415133

15-20 cmbs T26-6 and T26-7
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	.110	.742	-.364	47	.717	-.6860	1.8825	-4.4730	3.1011
	Equal variances not assumed			-.370	40.195	.714	-.6860	1.8564	-4.4374	3.0655
Elongation	Equal variances assumed	.145	.705	2.436	47	.019	.105808924	.043439711	.018419497	.193198351
	Equal variances not assumed			2.454	39.406	.019	.105808924	.043110693	.018638026	.192979822
Flatness	Equal variances assumed	.032	.860	-.376	47	.708	-.01407596	.037254537	-.08896458	.060928866
	Equal variances not assumed			-.379	39.403	.707	-.01401756	.036973241	-.08877592	.060743399
Blockiness	Equal variances assumed	2.250	.140	1.746	47	.087	.009707496	.005559274	-.00147322	.020891313
	Equal variances not assumed			1.988	45.830	.053	.009707496	.004882533	-.00012118	.019536510
Weight	Equal variances assumed	.000	1.000	-.006	47	.995	-.00619830	1.04269246	-2.1038041	2.091423380
	Equal variances not assumed			-.006	40.290	.995	-.00698830	1.027476490	-2.0824080	2.069942520

20-25cmbs T26-6 and T26-7
Group Statistics

	UNIT	N	Mean	Std. Deviation	Std. Error Mean
Length	T26-6	16	11.975	5.9179	1.4795
	T26-7	18	10.294	3.2027	.7549
Elongation	T26-6	16	.75828234	.184657886	.046164472
	T26-7	18	.64414112	.189466590	.044657704
Flatness	T26-6	16	.18566247	.067929293	.016982323
	T26-7	18	.23176529	.088600282	.020883287
Blockiness	T26-6	16	.03464550	.014227886	.003556971
	T26-7	18	.03160545	.014557822	.003431312
Weight	T26-6	16	7.45416667	3.674090968	.918522742
	T26-7	18	6.02777778	1.665264116	.392506516

20-25 cmbs T26-6 and T26-7
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	8.670	.006	1.046	32	.303	1.6806	1.6067	-1.5921	4.9532
	Equal variances not assumed			1.012	22.482	.322	1.6806	1.6609	-1.7597	5.1208
Elongation	Equal variances assumed	.314	.579	1.774	32	.086	.114141224	.064330030	-.01689459	.245177207
	Equal variances not assumed			1.777	31.709	.085	.114141224	.064229813	-.01677790	.245020238
Flatness	Equal variances assumed	1.736	.197	-1.686	32	.102	-.046102823	.027343788	-.10180296	.009594650
	Equal variances not assumed			-1.713	31.371	.097	-.046102823	.026916741	-.10097612	.008767966
Blockiness	Equal variances assumed	.124	.727	.614	32	.543	.003040047	.004949137	-.00701015	.013121110
	Equal variances not assumed			.615	31.692	.543	.003040047	.004942261	-.00703852	.013110947
Weight	Equal variances assumed	14.472	.001	1.486	32	.147	1.426388889	.959652405	-.52839092	3.381136870
	not assumed			1.428	20.379	.168	1.426388889	.998872060	-.65471905	3.507519683

25-30 cmbs T26-6 and T26-7
Group Statistics

	UNIT	N	Mean	Std. Deviation	Std. Error Mean
Length	T26-6	23	9.639	6.0420	1.2599
	T26-7	8	12.000	8.5749	3.0317
Elongation	T26-6	22	.76405451	.173235401	.036933912
	T26-7	8	.65351580	.120513076	.042607807
Flatness	T26-6	23	.22699072	.145755902	.030392207
	T26-7	8	.20087628	.094062808	.033256225
Blockiness	T26-6	23	.04404624	.034635800	.007222063
	T26-7	8	.02957391	.015420779	.005452069
Weight	T26-6	23	6.46666667	4.679344252	.975710725
	T26-7	8	7.03750000	4.800444341	1.697213373

25-30 cmbs T26-6 and T26-7
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Length	Equal variances assumed	2.502	.125	-.853	29	.401	-2.3609	2.7670	-8.0199	3.2982
	Equal variances not assumed			-.719	9.536	.489	-2.3609	3.2830	-9.7245	5.0027
Elongation	Equal variances assumed	1.685	.205	1.656	28	.109	.110538710	.066749270	-.02619971	.247268392
	Equal variances not assumed			1.960	18.071	.066	.110538710	.056387401	-.00789521	.228970942
Flatness	Equal variances assumed	1.379	.250	.471	29	.641	.026114433	.055453894	-.08730516	.139530382
	Equal variances not assumed			.580	19.293	.569	.026114433	.045051778	-.06808121	.120311987
Blockiness	Equal variances assumed	1.080	.307	1.134	29	.266	.014472329	.012767059	-.01163239	.040583896
	Equal variances not assumed			1.599	26.832	.121	.014472329	.009048937	-.00409998	.033044655
Weight	Equal variances assumed	.248	.622	-.295	29	.770	-.57083333	1.932803737	-4.5238829	3.382194162
	not assumed			-.292	11.975	.776	-.57083333	1.957688600	-4.8373182	3.695576515

APPENDIX C

RADIOCARBON DATES

Mr. Lawrence Todd | Report Date: 10/24/2006

Colorado State University | Material Received: 9/21/2006

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 221329 SAMPLE : U27-17-6 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 770 to 400 (Cal BP 2720 to 2350)	2380 +/- 40 BP	-21.7 o/oo	2430 +/- 40 BP
Beta - 221330 SAMPLE : U27-17-10 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 970 to 820 (Cal BP 2920 to 2760)	2710 +/- 40 BP	-23.3 o/oo	2740 +/- 40 BP
Beta - 221331 SAMPLE : U27-17-11 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal BC 1900 to 1690 (Cal BP 3850 to 3640)	3420 +/- 40 BP	-21.1 o/oo	3480 +/- 40 BP

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-21.7:lab. mult=1)

Laboratory number: **Beta-221329**

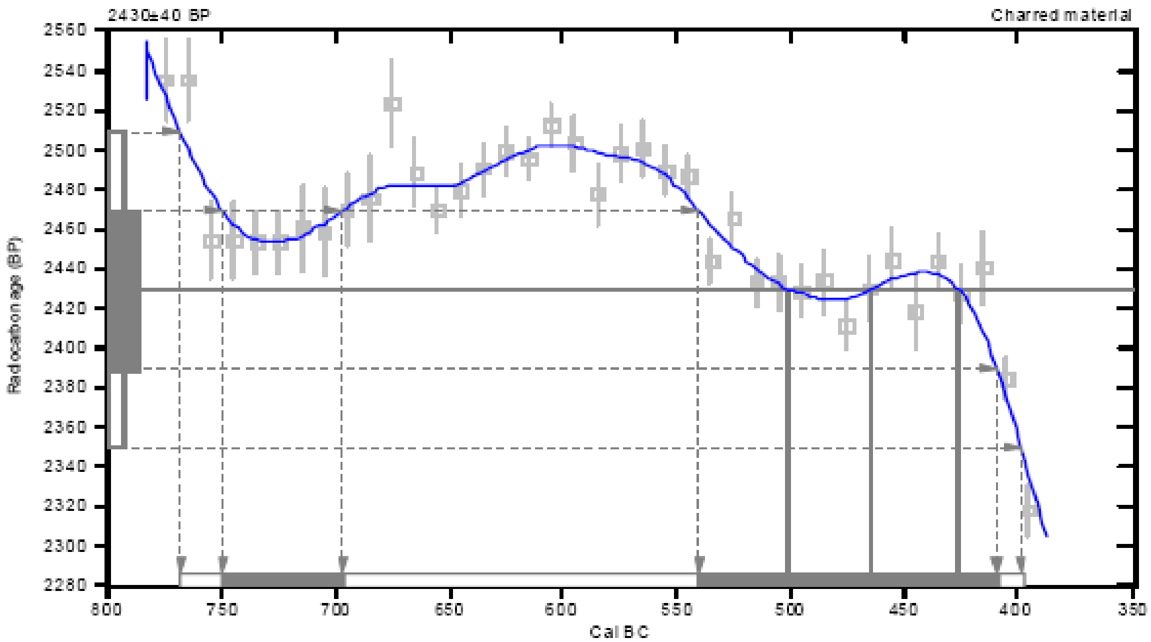
Conventional radiocarbon age: **2430±40 BP**

2 Sigma calibrated result: (95% probability) **Cal BC 770 to 400 (Cal BP 2720 to 2350)**

Intercept data

Intercepts of radiocarbon age with calibration curve: Cal BC 500 (Cal BP 2450) and Cal BC 460 (Cal BP 2410) and Cal BC 430 (Cal BP 2380)

1 Sigma calibrated results: (68% probability) Cal BC 750 to 700 (Cal BP 2700 to 2650) and Cal BC 540 to 410 (Cal BP 2490 to 2360)



References:

Database used
INTCAL98
Calibration Database
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INTCAL98 Radiocarbon Age Calibration
Stuiver, M., et. al., 1998, Radiocarbon 40(3), p1041-1083
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.3:lab. mult=1)

Laboratory number: **Beta-221330**

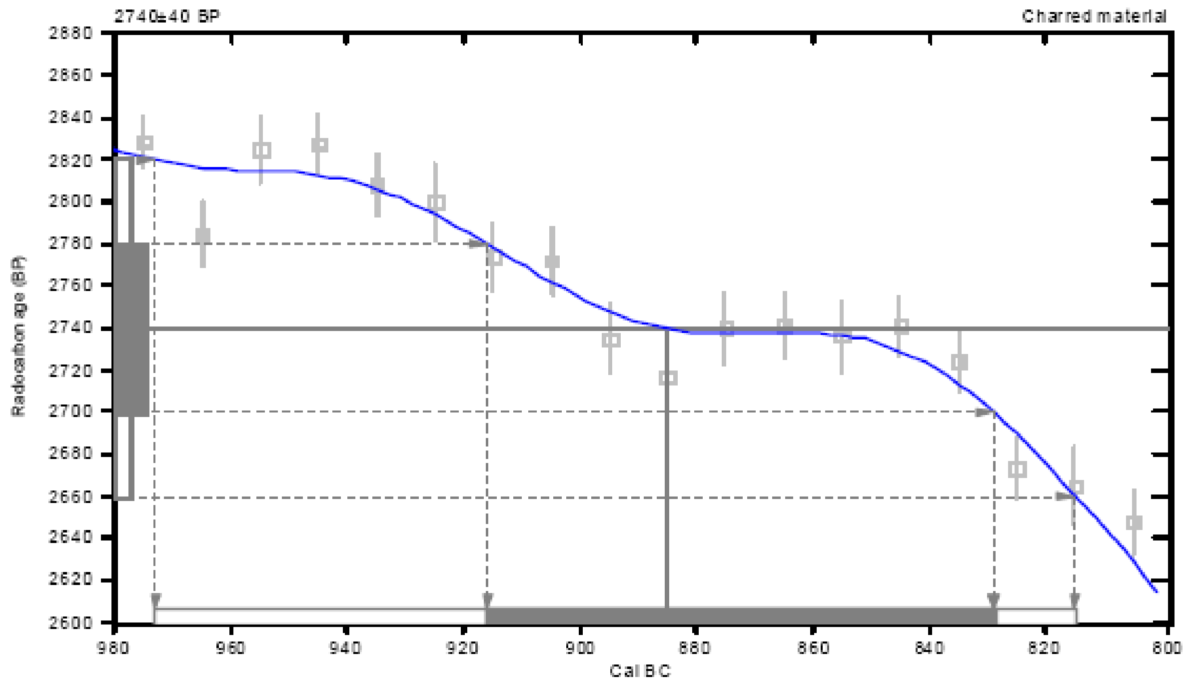
Conventional radiocarbon age: **2740±40 BP**

2 Sigma calibrated result: **Cal BC 970 to 820 (Cal BP 2920 to 2760)**
(95% probability)

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 880 (Cal BP 2840)

1 Sigma calibrated result: Cal BC 920 to 830 (Cal BP 2870 to 2780)
(68% probability)



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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-21.1:lab. mult=1)

Laboratory number: **Beta-221331**

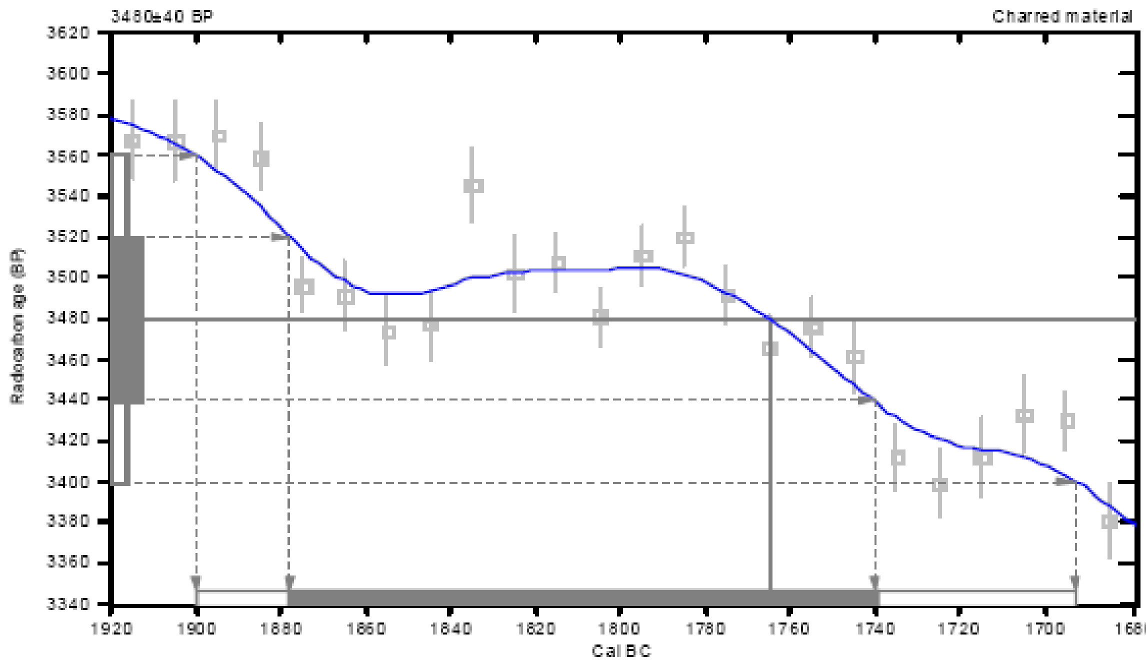
Conventional radiocarbon age: **3480±40 BP**

2 Sigma calibrated result: (95% probability) **Cal BC 1900 to 1690 (Cal BP 3850 to 3640)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal BC 1760 (Cal BP 3720)

1 Sigma calibrated result: (68% probability) Cal BC 1880 to 1740 (Cal BP 3830 to 3690)



References:

Database used

INTCAL98

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